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The problems and future requirements related to transportation on the Purdue University, Lafayette campus, are examined. After identifying a central academic zone, future requirements are estimated related to the pedestrian circulation system, pedestrian-vehicle conflicts, parking facilities, and mass transportation systems in the zone. A number of alternate plans are developed to meet the future needs of circulation within the academic zone as well as those of commuters. Recommendations are also made as to which plan ought to be implemented. A bibliography is included. (FS)

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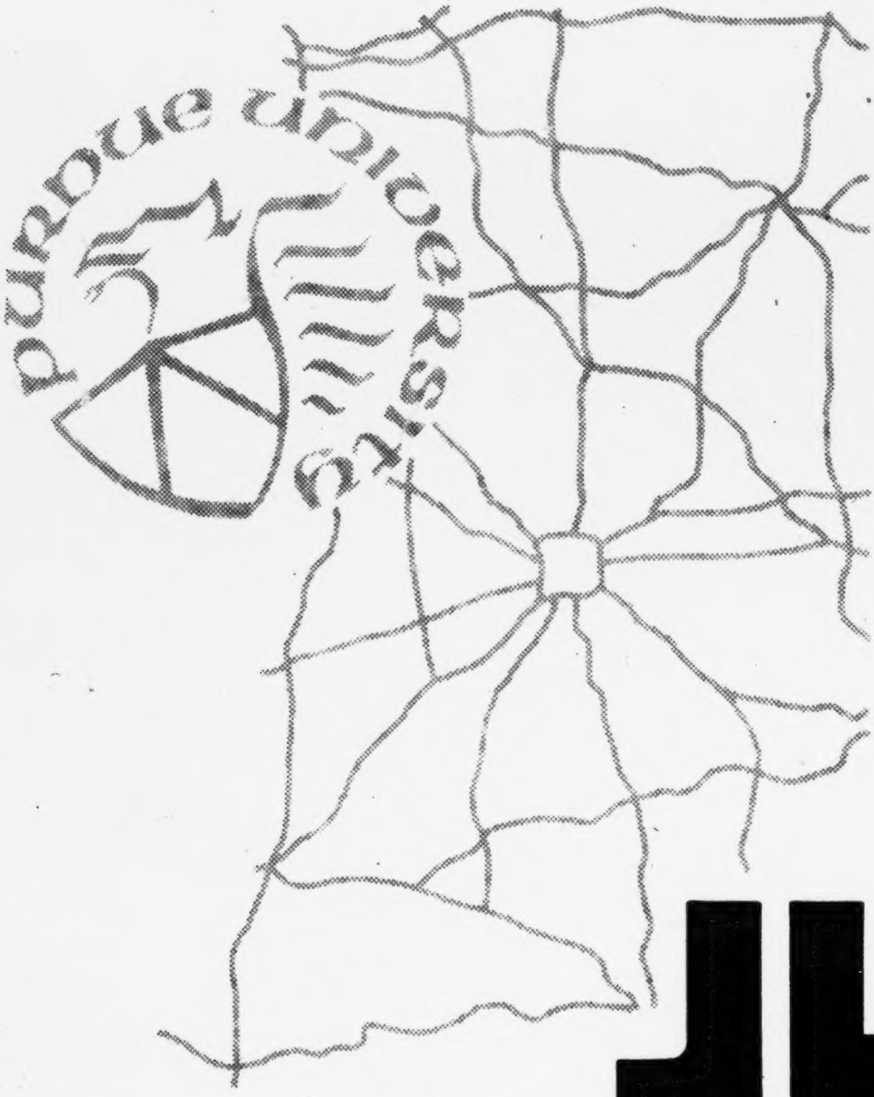
CAMPUS TRANSPORTATION PLANNING: A CASE STUDY OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

FEBRUARY 1969 - NUMBER 5



BY

MONIRA Y. FOUAD

JHRP

JOINT HIGHWAY RESEARCH PROJECT
PURDUE UNIVERSITY AND
INDIANA STATE HIGHWAY COMMISSION

EF003416

Final Report

CAMPUS TRANSPORTATION PLANNING: A CASE STUDY OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

To: J. F. McLaughlin, Director
Joint Highway Research Project

February 14, 1969

File: 9-12-2

From: H. L. Michael, Associate Director
Joint Highway Research Project

The attached Final Report "Campus Transportation Planning: A Case Study of the Lafayette Campus of Purdue University" has been prepared by Mrs. Monira Y. Fouad under the direction of Professor H. L. Michael. The research was financed by Purdue University. Mrs. Fouad also used the report as her thesis for the MS degree.

The study examined the future requirements of transportation on the Purdue Lafayette Campus. A number of feasible plans are examined to meet these transportation requirements for an ultimate campus population of 35,000 students.

The report is presented to the Board as information.

Respectfully submitted,

Harold L. Michael

Harold L. Michael
Associate Director

HLM:rg
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Final Report

CAMPUS TRANSPORTATION PLANNING: A CASE STUDY OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

by
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Joint Highway Research Project
File No: 9-12-2

Purdue University
Lafayette, Indiana
February 14, 1969

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ABSTRACT

Fouad, Monira Yehya. M.S., Purdue University, June 1969. CAMPUS TRANSPORTATION PLANNING: A CASE STUDY OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY. Major Professor: Harold L. Michael.

This study examined the problems and future requirements related to transportation on the Purdue Lafayette campus. A number of feasible alternative solutions were proposed to meet future transportation requirements for an established ultimate campus population.

On the campus, a central academic zone was identified as the locus of instructional, research, administrative, and assembly facilities. Pedestrian and automobile circulation in this zone and commuting to and from it were analyzed. Future requirements related to the pedestrian circulation system in the academic zone, to the major pedestrian-vehicle conflicts in and around the academic zone, and to parking facilities for students, staff, and visitors and/or mass transportation systems serving them were estimated.

A number of alternative plans were developed to meet the future needs for circulation in the academic zone and for commuting to and from it. These alternatives were evaluated in terms of cost as well as a number of other qualitative criteria. It was found by eliminating through

vehicular traffic on the north campus and by connecting it to the south campus through an open pedestrian underpass under State Street, that future pedestrian-vehicle conflicts in the academic zone could be minimized. Implementation of such a plan would only require reasonable changes in the existing conditions.

Insofar as commuting to and from the academic zone is concerned, two plans appeared to offer appropriate solutions. One of these by providing for future parking demands of students, staff, and visitors on close-by locations around the academic zone (mostly in multi-story garages) would offer a high level of convenience in terms of the trip times involved. The second by providing for the future parking demands in remote parking facilities connected to the academic zone by street bus systems would offer a lower annual cost than that of the first plan but not as high a level of convenience. It was recommended that the first plan be implemented.

CHAPTER I. INTRODUCTION

In many respects, a university campus resembles a city. Frequently, the size of the campus population (students, staff, and visitors) comes close to that of a small city. The activities performed on the campus are almost as complex and diversified as those performed in the city. The campus is not only a place for learning, for research, and for the development of the society's cultural life, but also a place where people live, work, shop, and move. To such extents, a university campus can be conceived as a micro-city to which many urban planning and transportation concepts are applicable.

In recent years, university campuses started to face the problems of population expansion. Their facilities, once simply laid out in close proximity to each other, had to expand upwards as well as outwards. Movement to and from these facilities and between them became more complex, intense, and time consuming. "Like most municipalities in the United States," writes Jakad, "American colleges and universities have come face to face with the explosive traffic problem." (1, p. 47)*

---

* Numbers in parentheses refer to numbered items in the List of References.

Both the campus population and the surrounding community suffered. Students are often obliged to walk longer distances than what is generally considered tolerable. They have to rush between classes to move from one building to another and in many cases, they have to cross heavy vehicular traffic. In the same time, automobile trips to the campus have become more difficult and time consuming due to lack of parking facilities on or around the campus. Traffic problems are equally felt by students, staff, and visitors. The surrounding communities also suffer from the intense traffic generated by the expanding campuses. The rapidly increasing enrollments and the mounting rates of automobile ownership and usage appear to be the two major factors behind campus transportation problems.

At already existing campuses, transportation problems are rendered even more severe by the inherited physical layout of buildings and circulation systems. At relatively old campuses, efforts were seldom made to provide an automobile-free environment. As a result, typical layouts inevitably create pedestrian-vehicle conflicts, especially in the central area of the campus where both pedestrian and vehicular traffic take place most intensely.

While many concepts and solutions have been presented to overcome (or at least to minimize) transportation problems for newly developed campuses, relatively little has been done to explore the possibilities of relieving existing campuses of such problems. The need exists to develop appropriate techniques to examine and analyze the transportation problems at already existing campuses as well as to develop sound and practical solutions to meet them.

Purpose and Scope

Purpose

The purpose of this study was to examine the nature and extent of the transportation problems on an already existing campus and to develop a number of alternative solutions to meet its future transportation requirements. The campus investigated in this study was the Lafayette campus of Purdue University. The study had the following specific objectives:

1. To develop an appropriate technique (or techniques) for examining the nature and magnitude of the transportation problems on an existing campus where the majority of the students were not commuters.
2. To estimate, for an ultimate campus population, the future campus transportation requirements.
3. To develop feasible alternative solutions to meet these estimated requirements.
4. To provide the decision-makers in the university with the necessary facts and evaluations about these developed alternatives.

Scope

In this study, the future campus transportation requirements are estimated for an ultimate campus population regardless of the future date at which this ultimate population might be reached. The study is limited to the investigation of campus transportation problems created by the traffic movements to and from as well as within the academic zone. As used in this study, traffic movements include both automobile and pedestrian traffic. The academic zone is defined as the locus of the contiguous instructional, research and administration functions of the campus. Traffic movements generated (or attacted) by peripheral areas of the campus represent a negligible fraction of the total traffic generated by the campus and are not considered in this study. Traffic routes to and from the surrounding community are also outside the scope of this study.

Emphasis is given to the movements of students to and from as well as within the academic zone. Movements of staff and visitors are also considered. Due account is given to the access of service and emergency vehicles.

Two main aspects related to campus transportation are analyzed: (1) pedestrian movements to and from as well as within the academic zone, and (2) parking demands of students, staff, and visitors on and around the academic zone.

The Lafayette Campus

The location of the Purdue Lafayette campus as related to the urban area (Lafayette and West Lafayette) is shown in Figure 1. The campus is located just west of the central business area of the city of West Lafayette and southwest of Northwestern Avenue, a major urban arterial. State Street, another major arterial, passes through the campus and a railroad line bounds it from the south. Community residential areas abut the east and northeast sides of the campus and open recreational areas surround both its west and northwest sides. Purdue's enrollment on this campus (23,370 in 1967/68) is, and has been, larger than what could be entirely accommodated by privately owned community housing facilities. The university, therefore, provides a substantial portion of the students' housing requirements. A general layout of the Purdue Lafayette campus appears in Figure 2.

Within the campus, the academic zone was delineated as the area where instructional, research, administrative, and principal assembly facilities are located. Figure 2 shows the delineation of the academic zone. State Street divides the academic zone into two parts referred to in this study as the north and the south campuses.

Previous Studies

Campus transportation problems are often studied in connection with campus physical planning. Few are the studies, however, that were primarily concerned with aspects of campus

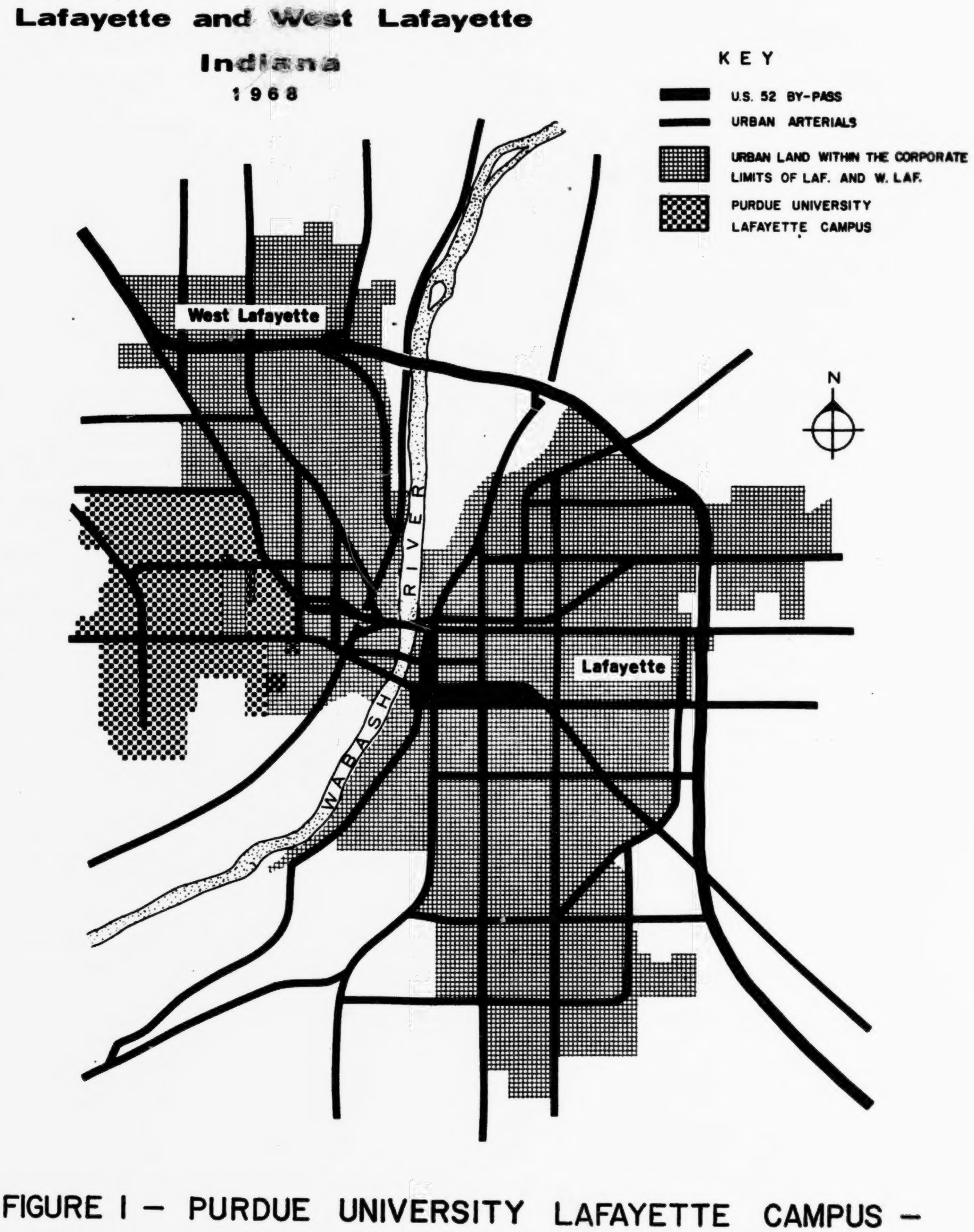

Lafayette and West Lafayette
Indiana
1968
KEY
U.S. 52 BY-PASS
URBAN ARTERIALS
URBAN LAND WITHIN THE CORPORATE LIMITS OF LAF. AND W. LAF.
PURDUE UNIVERSITY LAFAYETTE CAMPUS
N
West Lafayette
Lafayette
WABASH RIVER

FIGURE I — PURDUE UNIVERSITY LAFAYETTE CAMPUS — GENERAL LOCATION

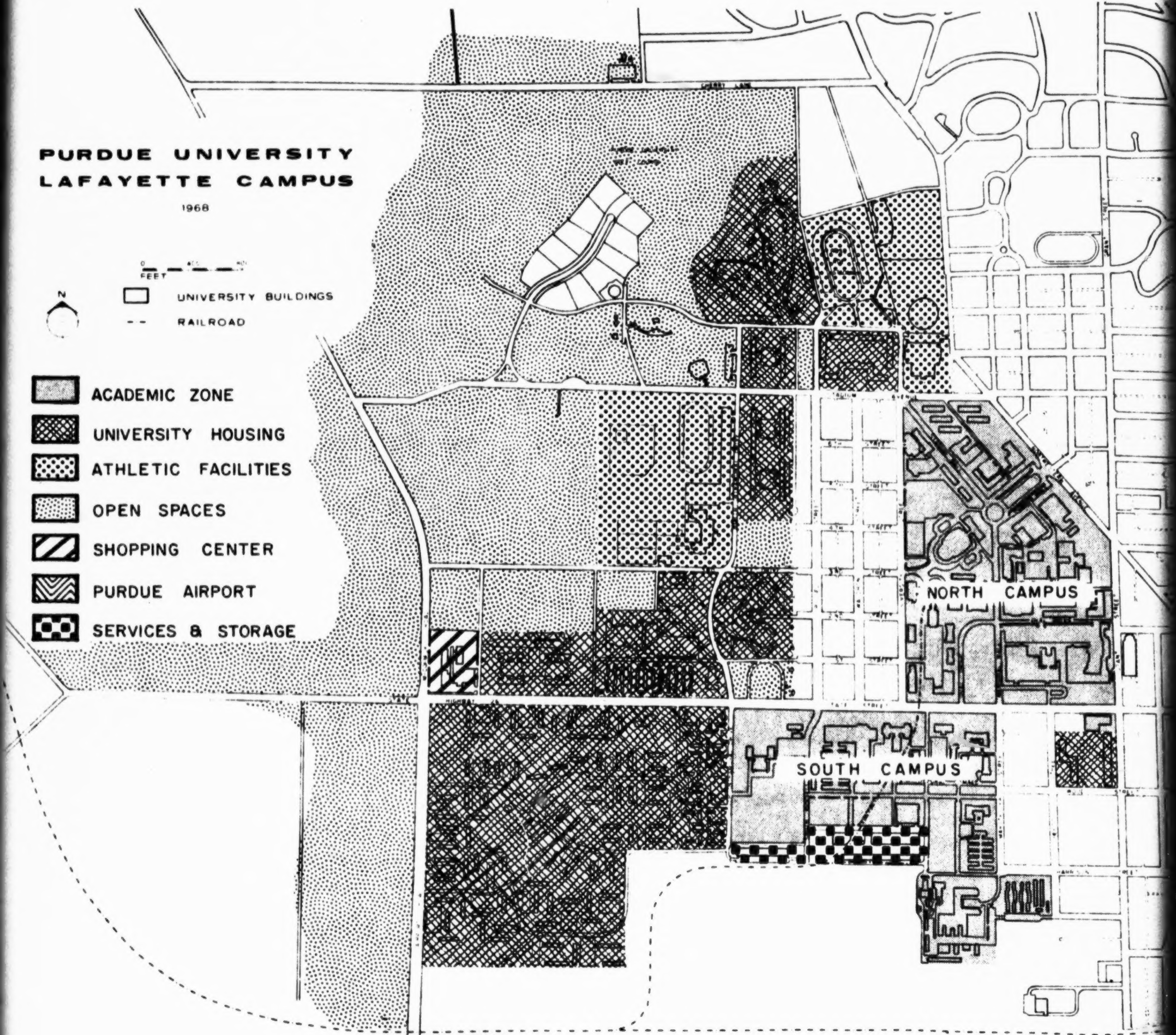
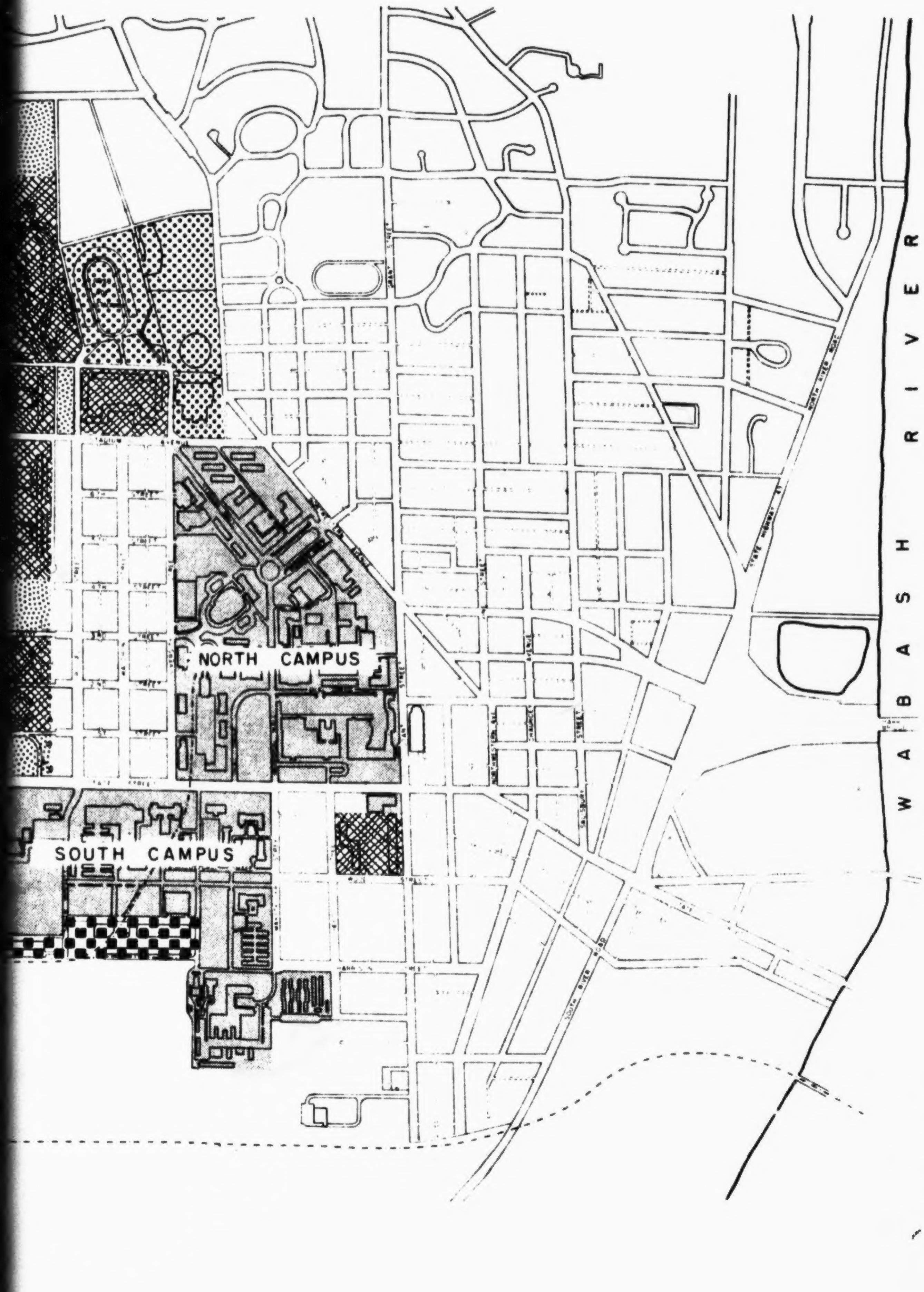

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
FEET
N
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
UNIVERSITY HOUSING
ATHLETIC FACILITIES
OPEN SPACES
SHOPPING CENTER
PURDUE AIRPORT
SERVICES & STORAGE
CHERRY LANE
NORTH CAMPUS
SOUTH CAMPUS

FIGURE 2 - PURDUE UNIVERSITY LAFAYETTE CAMPUS - GENERAL LAYOU


NORTH CAMPUS
SOUTH CAMPUS
W A B A S H R I V E R
NORTH RIVER ROAD
STATE HIGHWAY 43
NORTHWESTERN AVE.
SALISBURY
SOUTH RIVER ROAD

AMPUS — GENERAL LAYOUT

transportation. Fewer still are those directed to comprehensive campus transportation planning.

To examine the pedestrian traffic generated by students on university campuses, the Educational Facilities Laboratories and Duke University developed a computer aided technique to simulate pedestrian traffic patterns by using information reported by a sample of students in the form of diaries. By means of the proposed technique, existing pedestrian traffic maps can be plotted. Future pedestrian traffic volumes and patterns can also be estimated (2). While the technique is conceptually sound, it has a number of operational limitations. The difficulties of obtaining diary information and the conceivable inaccuracies involved in using them (especially in forecasting) tend to limit the usefulness of the technique.

The University of Michigan and the University of Mississippi used an observed vehicle trip generation rate per capita (to the campus) to estimate future vehicular traffic (3,4). Although Dober recognized the simplicity of using such observed rates, he pointed out that consideration should be given to other factors such as changes in university housing supply, changes in the populations of graduate and married students, improvements in mass transportation systems, and increasing campus parking supply (5).

In preparing parking plans for the University of Illinois and the University of Mississippi, Bartholomew & Associates stressed the importance of considering vehicle ownership trends in estimating parking demands. He also pointed out that the policies adopted by the university relative to parking supply, fees, and controls have a great influence on parking demand. Accordingly, Bartholomew developed a number of alternative parking plans assuming different levels of future demand. The level of demand that could be economically met was, then, selected. The university's future parking policies were planned accordingly (4,6). Provided that the assumed alternate levels of parking demand are realistically established on the basis of observed parking habits and patterns, this approach can provide sound estimates of future campus parking requirements.

Marconi investigated the factors affecting parking demand on two different campuses in San Francisco. He found that parking demand was substantially higher on the campus that had the higher percent of non-resident students (7). In essence, these results indicated that the distances from the students' residences to the campus have a decisive effect on the rates of automobile usage and consequently on the parking demand.

The variables most often pointed out in the several studies found in the literature as influencing campus traffic and parking demands are: (1) size and composition of the campus population, (2) proportion of resident students living in university housing facilities, (3) class schedules and office hours, (4) availability and conditions of mass transportation, (5) university parking policies, and (6) parking availability and fees in the surrounding community (3-8).

While variables affecting campus transportation have been separately recognized and used, it appears that no comprehensive technique has yet been developed to include a combination of these variables in estimating future campus traffic and parking demands.

Procedure

In this study, two major phases of campus transportation are considered. First, movement in the academic zone is examined. The efficiency of pedestrian circulation is analyzed in terms of trip lengths and frequencies. Inefficiencies in the existing layout and uses of instructional facilities are pointed out. Locations and intensities of pedestrian-vehicle conflicts are also discussed. Second, commuting to and from the academic zone is subjected to a detailed analysis. Four campus population characteristics are considered to have a combined effect on the numbers of trips made to and from the academic zone in different hours and on the modes of travel used in these trips. First, the size and composition of the campus population (students, staff, and visitors) is used in determining the magnitude of traffic movements to and from the academic zone. Second, the numbers of users of instructional facilities, offices, and other assembly facilities in the academic zone (referred to in this study as the daytime population) provides the basis for examining the temporal patterns of traffic movements to and from the academic zone. Third, the students' behavioral patterns in using their automobiles to and from the academic zone are examined. Based on these patterns, probabilities of automobile usage by students living at different distances from the academic zone are established. Fourth, the residential distribution of students (both in university housing facilities and in the surrounding community housing) is used to establish the proportions (and numbers) of students living at different distances from the academic zone. On the basis of the observed patterns of automobile usage, the students' residential distribution is used to estimate the expected numbers of student auto trips (and non-auto trips) made to the academic zone. Since almost all staff members and visitors, regardless of where they live, tend to use their automobiles to commute to the academic zone, their residential distributions were not considered.

The present university regulations on traffic and parking, the existing conditions of relative parking availability on and around the academic zone, and the existing patterns of automobile usage in commuting to the academic zone are assumed to remain almost unchanged for the future.

For an established ultimate campus population, the future patterns and magnitudes of vehicular and pedestrian traffic movements in as well as to and from the academic zone are estimated on the basis of the above assumptions and the analyses of the existing traffic movements. Future transportation requirements (in terms of pedestrian walkways, parking facilities, and/or mass transportation systems) are determined. Several alternative plans are developed to meet the future needs for circulation in the academic zone and for commuting to and from it. These alternatives are evaluated in terms of cost as well as a number of other qualitative criteria. Conclusions are drawn and recommendations made.

CHAPTER II. DATA COLLECTION, DATA ANALYSIS, AND FORECASTING

The following is a discussion of the data collected for this study, the analyses performed on each data item, and the forecasting of future conditions relevant to campus transportation planning. In the following discussions, the term student is used to indicate full-time and part-time registered students. By staff is meant all full-time members of the faculty and of the clerical and service staffs. Instructional facilities refer to buildings where classes or laboratory sessions are held.

Movement in the Academic Zone

Movement in the academic zone is mainly done by foot. Vehicular movement is relatively limited. However, pedestrian-vehicle conflicts exist at certain locations in the zone. The analysis of the movement in the academic zone, therefore, focused on two aspects: (1) the efficiency of pedestrian circulation (and the general layout of the different facilities), and (2) the pedestrian-vehicle conflicts. Since students represent the majority of pedestrians in the academic zone, only their movement was considered. The analysis provided the basis for developing proposals to minimize pedestrian-vehicle conflicts and for making recommendations on the future layout of facilities in the academic zone. Student pedestrian trips are unique in that their origins and destinations (in the academic zone) are mainly dictated by class schedules, the time-break allowed between classes, the locations of the existing facilities, and the use of these facilities. The analysis, therefore, took into consideration these fundamental temporal and spatial determinants of pedestrian circulation in the academic zone.

The Efficiency of Pedestrian Circulation

Ideally, facilities most used in common should be centrally located to be most accessible from all other locations in the academic zone. Instructional facilities should also be located within "walkable" distances from each other; "walkable" within the time-break allowed between classes. Under these ideal conditions, a relationship between pedestrian trip lengths and trip frequencies would show a high frequency of short trips with a decreasing frequency as trip length increases. Such an ideal pattern may not be found on all existing campuses. However, an analysis of the existing relationship between trip lengths and frequencies provides a measure of the degree to which the ideal is fulfilled. The analysis was thus performed as follows.

For each instructional facility in the academic zone, the weekly total number of student contact hours was used to estimate the average daily pedestrian trips attracted by the facility (9).* Non-instructional facilities were not considered. Estimates on average daily pedestrian trip ends by facility were obtained for both the Spring and Fall semesters of 1967. Results obtained for both semesters did not show appreciable differences. Figure 3 shows groupings of instructional facilities according to their estimated average daily pedestrian trip ends for the Fall of 1967. Presently, the time-break allowed between classes is ten minutes, about two minutes of which are usually spent in going in and out of classrooms and going up and down staircases at both origin and destination. The actual walking should thus be done in eight minutes. Because instructional facilities are presently classified and used by major fields (Electrical Engineering, Physics, Chemistry...etc.) and not by functions (lecture halls, laboratories, offices... etc.), linkages exist (from a circulation standpoint) between each instructional facility and virtually all others.

To examine the efficiency of the existing layout of facilities and the pedestrian circulation system, a hypothetical non-problematic circular zone was delineated whose diameter can be walked within eight minutes at an average speed of about 275 feet per minute.** By superimposing the

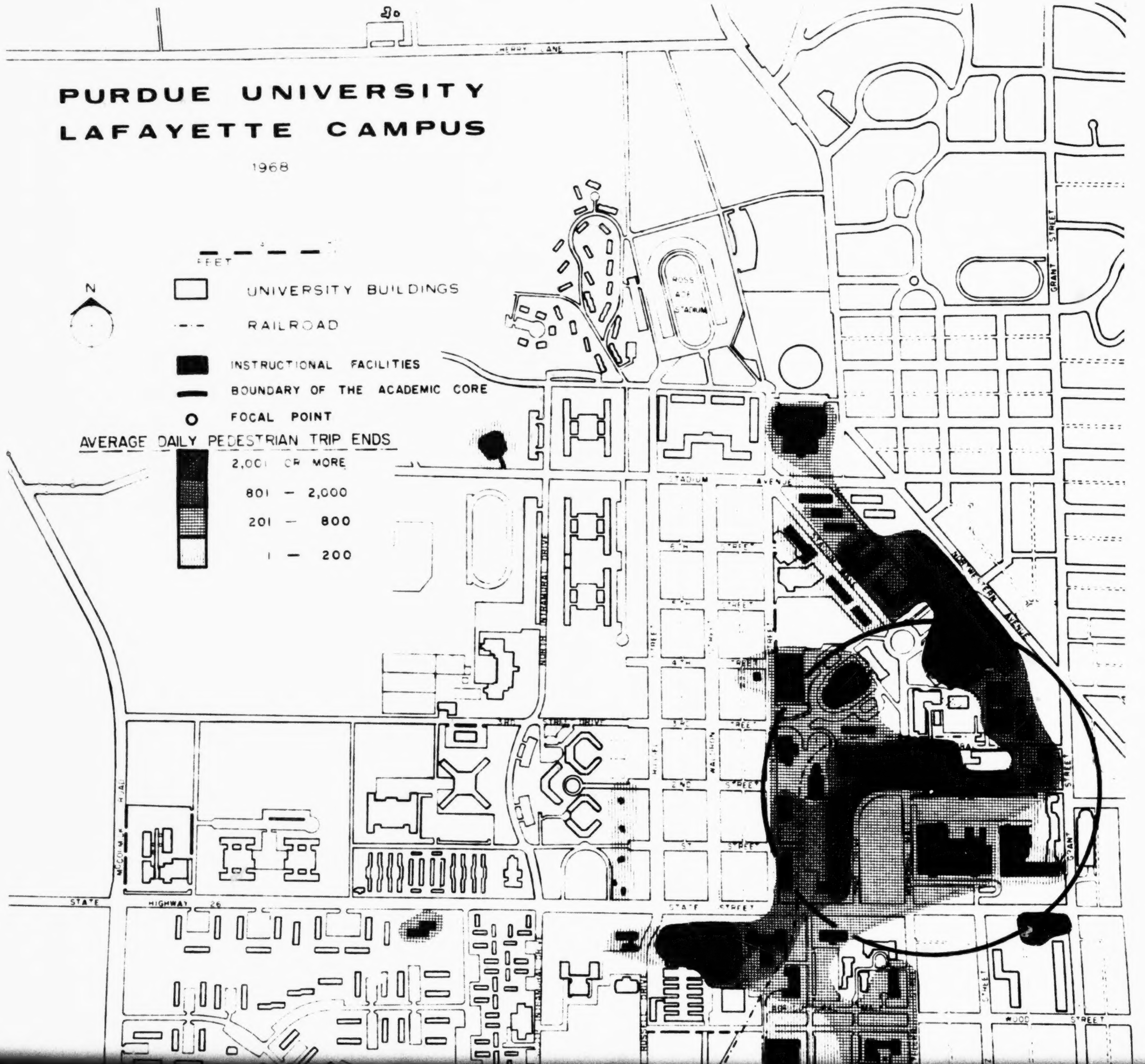
---

* A student contact hour refers to one student attending one instructional session. Every class contact hour and every three laboratory contact hours were considered equivalent to one pedestrian trip.

** A recent standard observed in a survey conducted at Cornell University (10).

PURDUE UNIVERSITY
LAFAYETTE CAMPUS

1968


FEET
N
UNIVERSITY BUILDINGS
RAILROAD
INSTRUCTIONAL FACILITIES
BOUNDARY OF THE ACADEMIC CORE
FOCAL POINT
AVERAGE DAILY PEDESTRIAN TRIP ENDS
2,001 OR MORE
801 — 2,000
201 — 800
1 — 200
PERRY LANE
GRANT STREET
ROSS ADE STADIUM
STADIUM AVENUE
NORTHWESTERN AVENUE
NORTH INTRAMURAL DRIVE
6TH STREET
5TH STREET
4TH STREET
3RD STREET DRIVE
2ND STREET
1ST STREET
WALDRON
STATE STREET
STATE HIGHWAY 26
McCORMICK ROAD
GRANT STREET
WOOD STREET
RUSSELL DRIVE

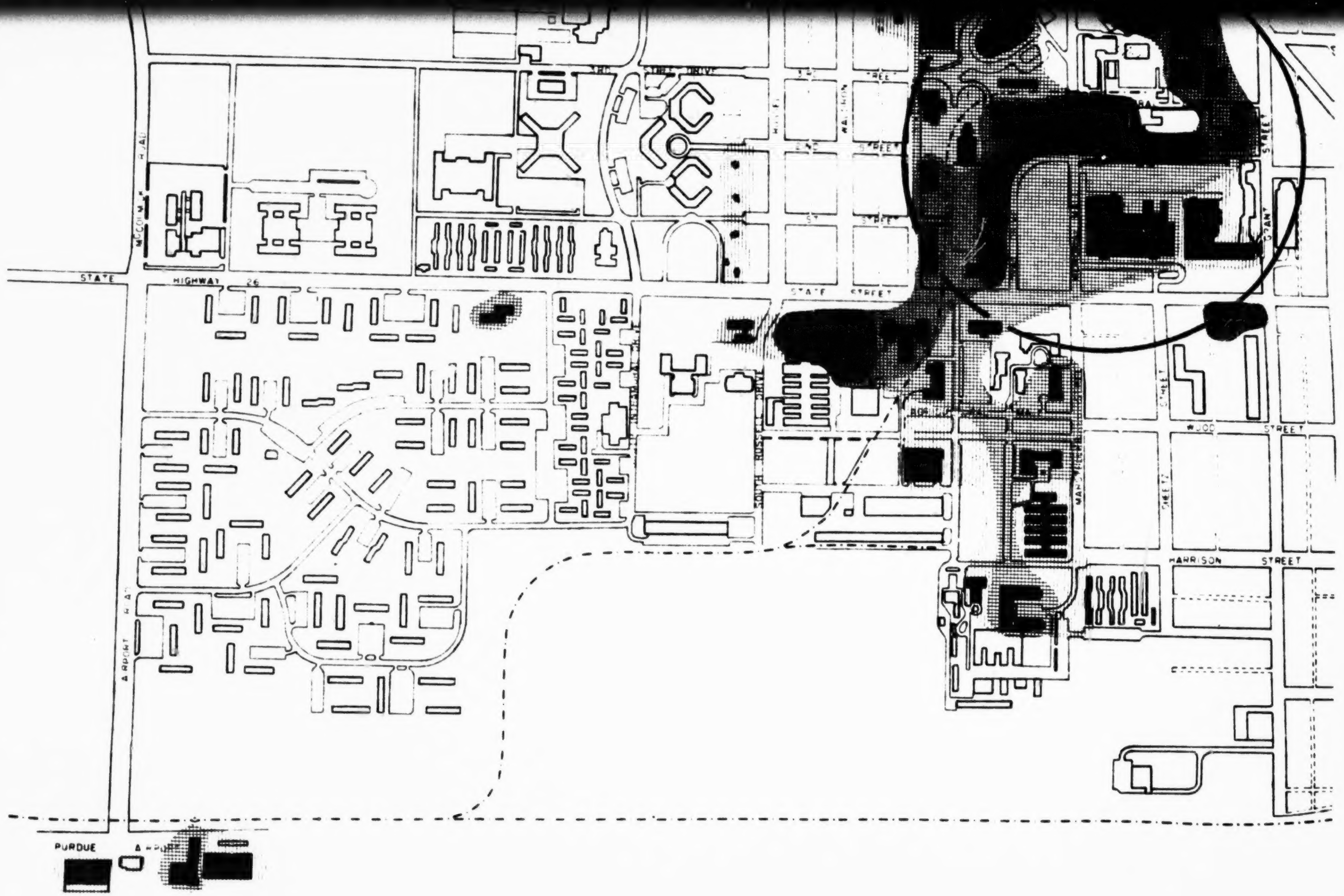

STATE
HIGHWAY 26
STATE STREET
MCCORMICK ROAD
AIRPORT ROAD
PURDUE AIRPORT
GRANT STREET
WOOD STREET
HARRISON STREET

FIGURE 3 - AVERAGE DAILY PEDESTRIAN TRIP ENDS TO INSTRUCTIONAL FACILITIES, FALL 1967

hypothetical zone on a map of the existing academic zone, a position was found that allows inclusion, within the non-problematic "core," of the maximum number of instructional facilities with the highest frequencies of use (Figure 3). The center of this "core" (referred to later as the focal point) was considered as the theoretical center of the academic zone. The actual trip lengths from the focal point to each instructional facility were measured and a relationship between trip lengths and frequencies was established. Figures 4 and 5 give the estimated average daily pedestrian trip ends by instructional facility by distance from the focal point for the Spring and Fall semesters of 1967.

The analysis shows that pedestrian trips exist that cannot be walked in eight minutes. However, no conclusive data were available to show how many such trips had to be made between two consecutive classes. Thus, the magnitude of these problematic trips could not be determined. The analysis, however, indicates that the present layout and use of the instructional facilities within the academic zone does not provide the most efficient linkages between facilities and hence does not minimize pedestrian travel. Some heavily used instructional facilities are located outside the non-problematic "core" (e.g., Life Science and Physics Buildings) while inside it are located some totally non-instructional facilities (e.g., the Engineering Administration building, the heating and power plant, and the Heavilon

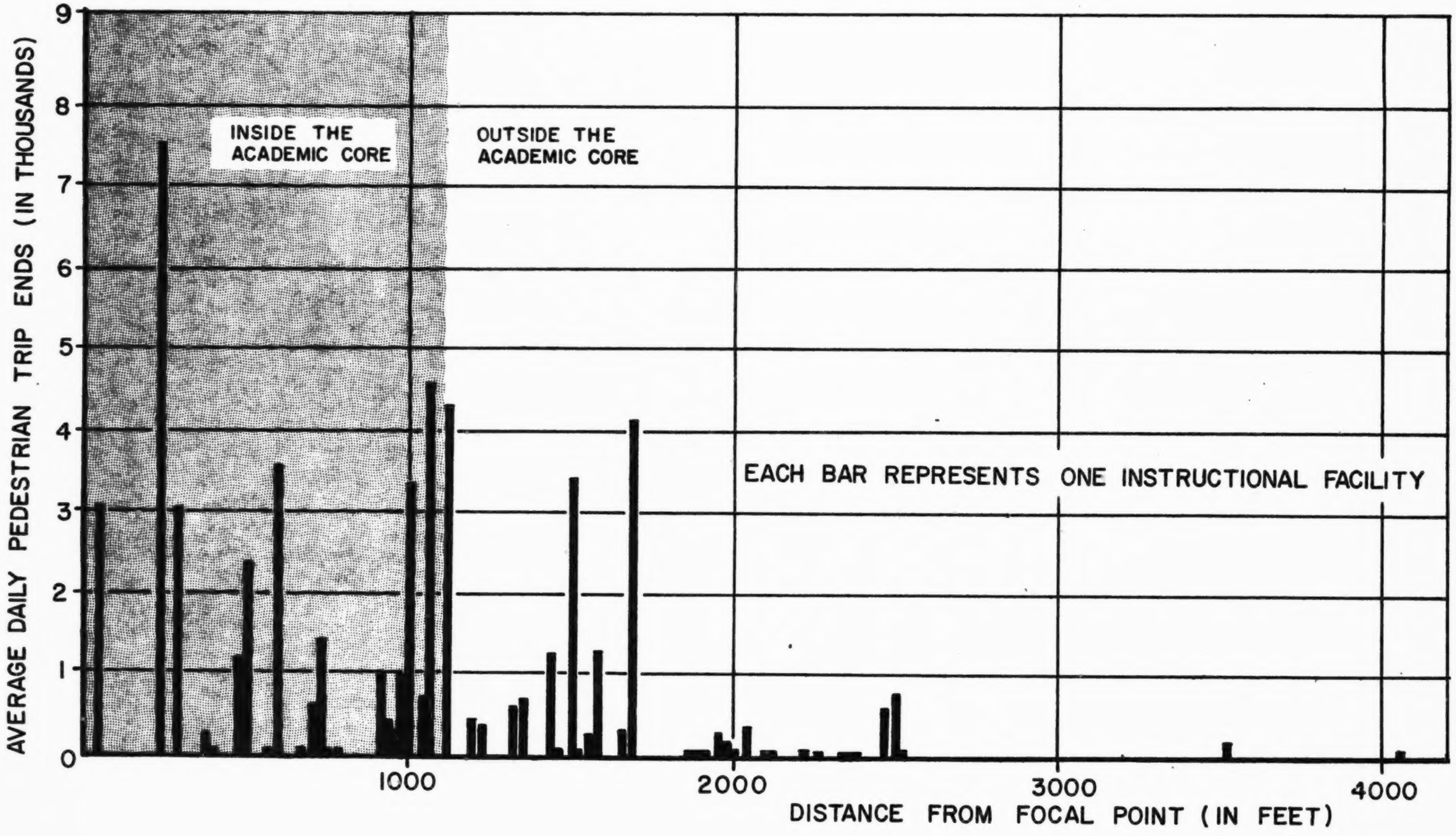


FIGURE 4 – AVERAGE DAILY PEDESTRIAN TRIP ENDS BY INSTRUCTIONAL FACILITY BY DISTANCE FROM THE FOCAL POINT, SPRING 1967

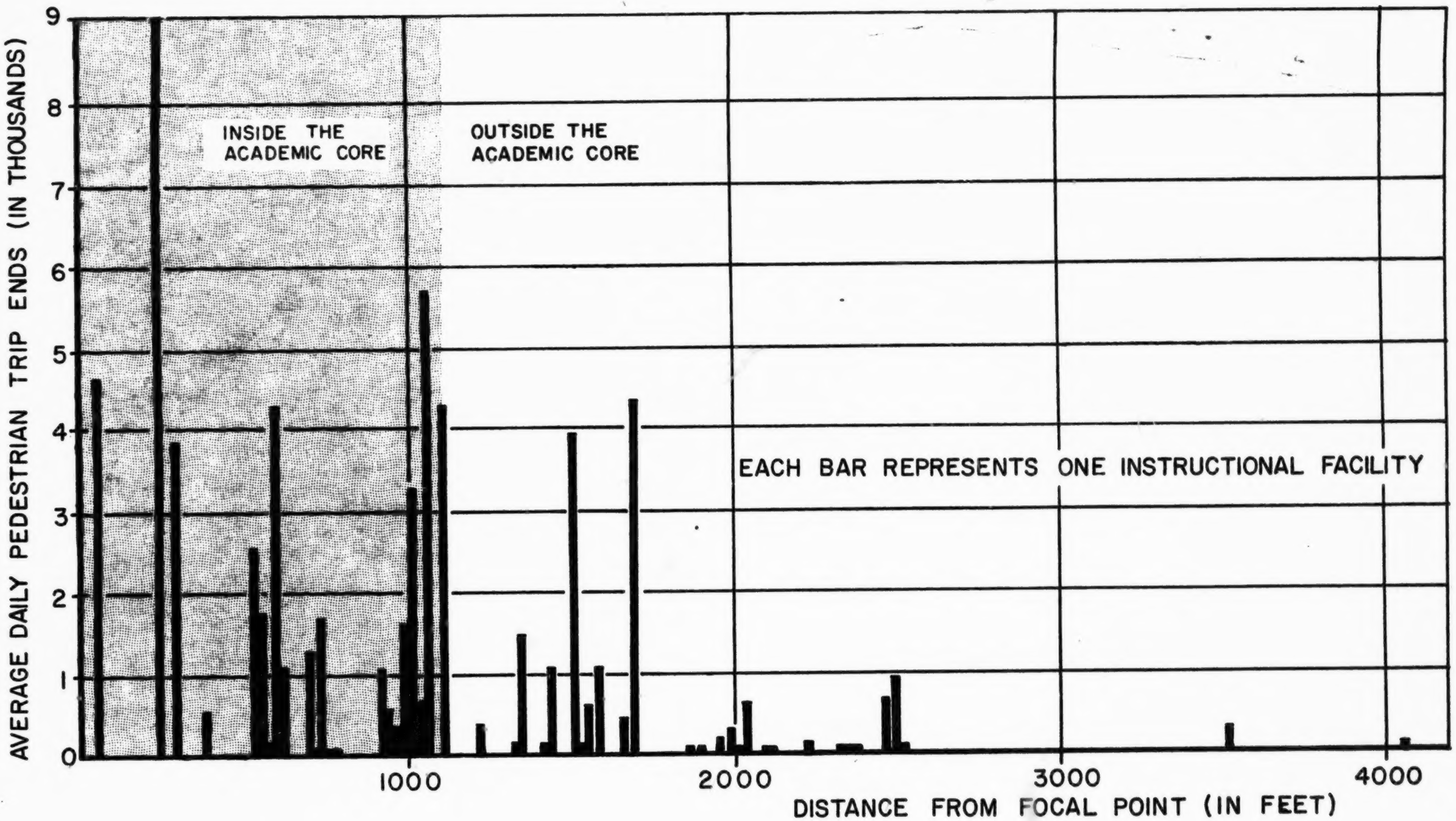


FIGURE 5 — AVERAGE DAILY PEDESTRIAN TRIP ENDS BY INSTRUCTIONAL FACILITY BY DISTANCE FROM THE FOCAL POINT, FALL 1967

Hall Laboratory building) and some infrequently used instructional facilities (e.g., Pierce Conservatory building and the Aeronautical and Engineering Sciences building).

Pedestrian-Vehicle Conflicts

The existing network of pedestrian paths in the academic zone was examined to determine the locations of pedestrian-vehicle conflicts. Major conflicts take place on State Street. Although fences and signals are provided to control pedestrian crossings between the north and south campuses, major conflicts still exist in a number of locations such as in front of the Home Economics buildings and the Krannert building. On the north campus, vehicular through traffic is presently discouraged by blocking portions of some internal streets. But a number of problematic points still remain on Oval Drive, Memorial Mall, Stadium Mall, Purdue Mall and south of the Hall of Music. Pedestrian-vehicle conflicts are almost absent on the south campus. The railroad line that passes through the academic zone does not seem to cause any real problem. However, it is aesthetically incompatible with the academic surrounding.

In the future, the volumes of pedestrian traffic will tend to increase in proportion to the expected increase in campus population. This calls for appropriate future actions to minimize the pedestrian-vehicle conflicts pointed out above and to maximize the efficiency of pedestrian circulation in the academic zone. With this in mind, a number of alternative circulation plans (in the academic zone) are developed in the next chapter. A number of recommendations concerning the future layout and use of different facilities in the academic zone are also given in Chapter IV.

Commuting to and from the Academic Zone

In this section, the campus population characteristics influencing commuting are first considered. Future commuting demands are then estimated.

Campus Population Characteristics Influencing Commuting

Data were collected on four characteristics of the campus population:

1. The size and the composition of the campus population (students, staff, and visitors).
2. The daytime population in the academic zone.
3. The student auto trips (home based).
4. The residential distribution of students on and around the campus.

The first, second, and fourth data items were obtained from the university records (11, 14-19, 21-23). The third was obtained by direct observation. In several cases, data from past years were used to ascertain whether or not noticeable trends existed.

Analyses were performed on these data to make possible the forecasting of future characteristics of campus population and hence future commuting demands. The results of a faculty questionnaire on policies affecting the development of a university master plan was constantly used for guidance in analysis and forecasting (14).*

Campus Population: Size and Composition. Three principal campus population subgroups were considered: students, staff, and visitors. For each, the existing size and composition are discussed and the future size and composition are estimated.

Students. Students represent the greatest proportion of the campus population. In the Fall of 1967, Purdue enrolled about 23,370 students on the Lafayette campus. Like on many other campuses, enrollment has greatly increased during the past few years. Figure 6 shows the increase in the total enrollment on the Lafayette campus during the period 1956-1967 (11). In general, evidence indicates that a growing percentage of the population seeks higher education and that this percentage will most likely continue to increase in the future (5). The enrollment on the Lafayette campus is thus expected to grow. The question is not how far it will grow but rather how far it should be allowed to grow. The problem of an optimum enrollment size has repeatedly been raised (10,12,13). Some believe that universities have already exceeded the ranges of optimum enrollment. Others think more students can still be accommodated. There appears to be no

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* A summary of the results of this questionnaire appears in Appendix A.

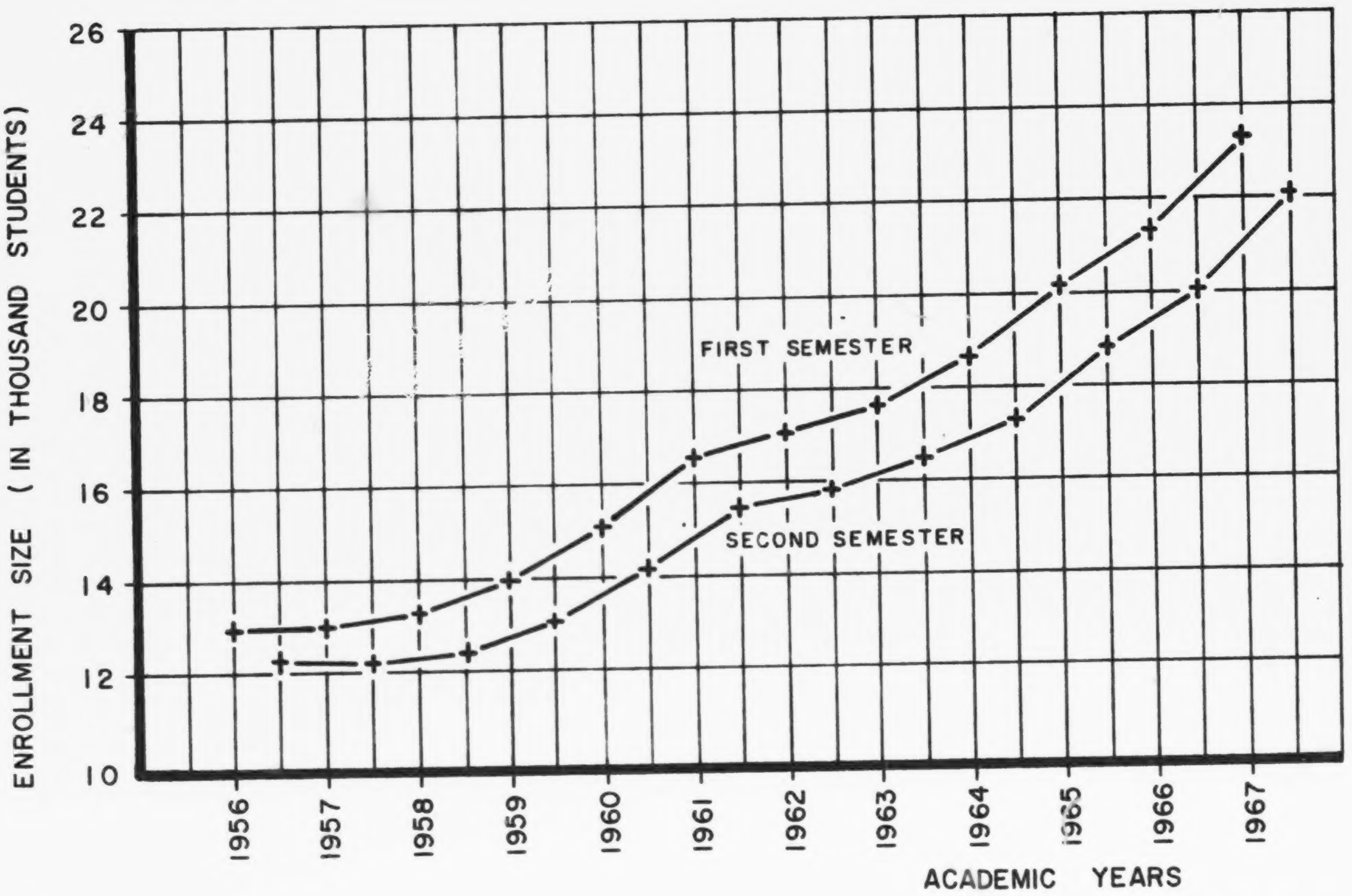

FIGURE 6 - ENROLLMENT ON THE LAFAYETTE CAMPUS, 1956-1967

general agreement as to what constitutes an optimum enrollment size.

In this study, the ultimate future enrollment size was determined on the basis of two criteria: (1) the opinions of university faculty members, and (2) the capacity of the existing academic zone. The faculty members seemed to reach a concensus of opinion that enrollment on the campus should be limited to 35,000 students (14). Assuming that the present land area of the academic zone will remain virtually unchanged in the future, and that the building standards (average number of stories, average land coverage ratios, and average gross built-up area per student) presently existing for the university (15) will be applied in the future, it was found that the academic zone can easily accommodate the ultimate enrollment agreed upon by the faculty. The ultimate future enrollment on the Lafayette campus was thus taken as 35,000 students.

From a campus transportation standpoint, two student population characteristics were found to be important: marital status and educational level (graduate or undergraduate). Only these two characteristics were found to correlate with the residential distribution of students and hence influence their choice of mode of travel (automobile versus walking) to and from the academic zone.

In the Fall of 1967, about 52.5 percent of the graduate students and about 10 percent of the undergraduate students were married. For both subgroups (graduate and undergraduate), these percentages remained almost unchanged during the period 1956-1967. For each subgroup, the future percentage of married students was assumed to remain the same as the average percentage of married students during the period 1956-1967; namely, 55 percent for the graduate students and 11 percent for the undergraduates.

To estimate the future total numbers of married students, the proportions of graduate and undergraduate students were examined. Since these proportions depend mainly on the University's educational philosophies, the opinions of faculty members were again consulted. Faculty members tended to agree that, in the future, the proportion of graduate students should be about 35 percent of the total enrollment (compared to about 23 percent in 1967) (14). Knowing that the future total enrollment is expected to reach 35,000 students, that 35 percent of these will be graduate students and that 55 percent of the graduate students and 11 percent of the undergraduates will be married, it was estimated that the number of married students will reach 9,240 students, or about 26.4 percent of the future ultimate enrollment.

Staff. Past trends indicate that the ratio of staff to students is almost entirely a matter of university policy. Therefore, estimates of the future number of full-time staff members were again based on the opinions of members of the faculty.

The results of the faculty questionnaire indicated a fairly consistent agreement on a future ratio of 0.27 full-time employees per student (14,16). Accordingly, it was estimated that, when ultimate enrollment is reached, the university will employ about 9,450 full-time staff members.

Visitors represented only a small percentage of the campus population. They are mainly attracted to the campus by special seminars, meetings, conferences, exhibits, and other periodic events conducted in the academic zone. As such, the future numbers of visitors are difficult to estimate. An approximate method, therefore, was used to estimate the future number of visitors parking in the academic zone by observing, for three different years, the ratio between the number of parking spaces (in the academic zone) used by visitors and by staff members, and by assuming that the average observed ratio (one parked visitor per 20 parked staff members) will remain almost constant in the future.

Daytime Population in the Academic Zone. The analysis of daytime population deals with the temporal distribution of the campus population in the academic zone. From a campus transportation standpoint, the interest focuses predominantly on periods of peak population concentrations in the academic zone since these peak periods produce parallel peak transportation demands. Besides, more specific aspects related to the concentration of students in the academic zone in morning hours are also of interest in determining the expected loads on mass transportation systems that might be developed (as an alternative solution) to students' commuting needs.

Students. The numbers of students present in the academic zone at different hours on an average weekday were determined by two factors:

1. The university master schedule assigns the weekdays and the hours on which different courses are given. As such, it determines the total numbers of students using scheduled facilities in the academic zone at different hours.
2. The students' use of non-scheduled facilities such as libraries, cafeterias, and student offices determines the total numbers of students present in the academic zone while not attending classes.

Information on the space utilization of different scheduled facilities was obtained from university records in the form of student contact hours (available by day and hour for past semesters)(17). A student contact hour represents one student present in an instructional facility in one class period. By summing these student contact hours for all scheduled facilities in the academic zone by day by hour, the total number of students present in scheduled facilities at different hours was obtained for two Fall semesters (66/67 and 67/68) and two Spring semesters (66/67 and 67/68). The proportions these totals represented of the total enrollment (for these semesters) were obtained. No significant differences were observed between the results obtained for these four semesters. Their average was used to represent the existing conditions. Figure 7 shows the average percentages of students present in scheduled facilities at different hours on an average weekday for the four semesters.

In the future, these observed percentages were also assumed to apply. Since the master schedule presently used by the university has initially been developed to optimize the use of instructional facilities, any future deviation from it would either mean class conflicts for more students or an inefficient utilization of instructional facilities. Accordingly, the existing percentages of students present in scheduled facilities at different hours on an average weekday (as determined by the master schedule) were assumed to remain almost unchanged for the future.

To estimate the future proportions of students using non-scheduled facilities, past and present data on the use of different libraries and the meals served in different cafeterias were obtained and analyzed (18,19). The proportions of graduate students present in offices in the academic zone were also estimated.

For libraries and cafeterias, two use characteristics were considered: (1) the total numbers of daily users in relation to the total enrollment, and (2) the proportions of these daily users present in the facilities at different hours

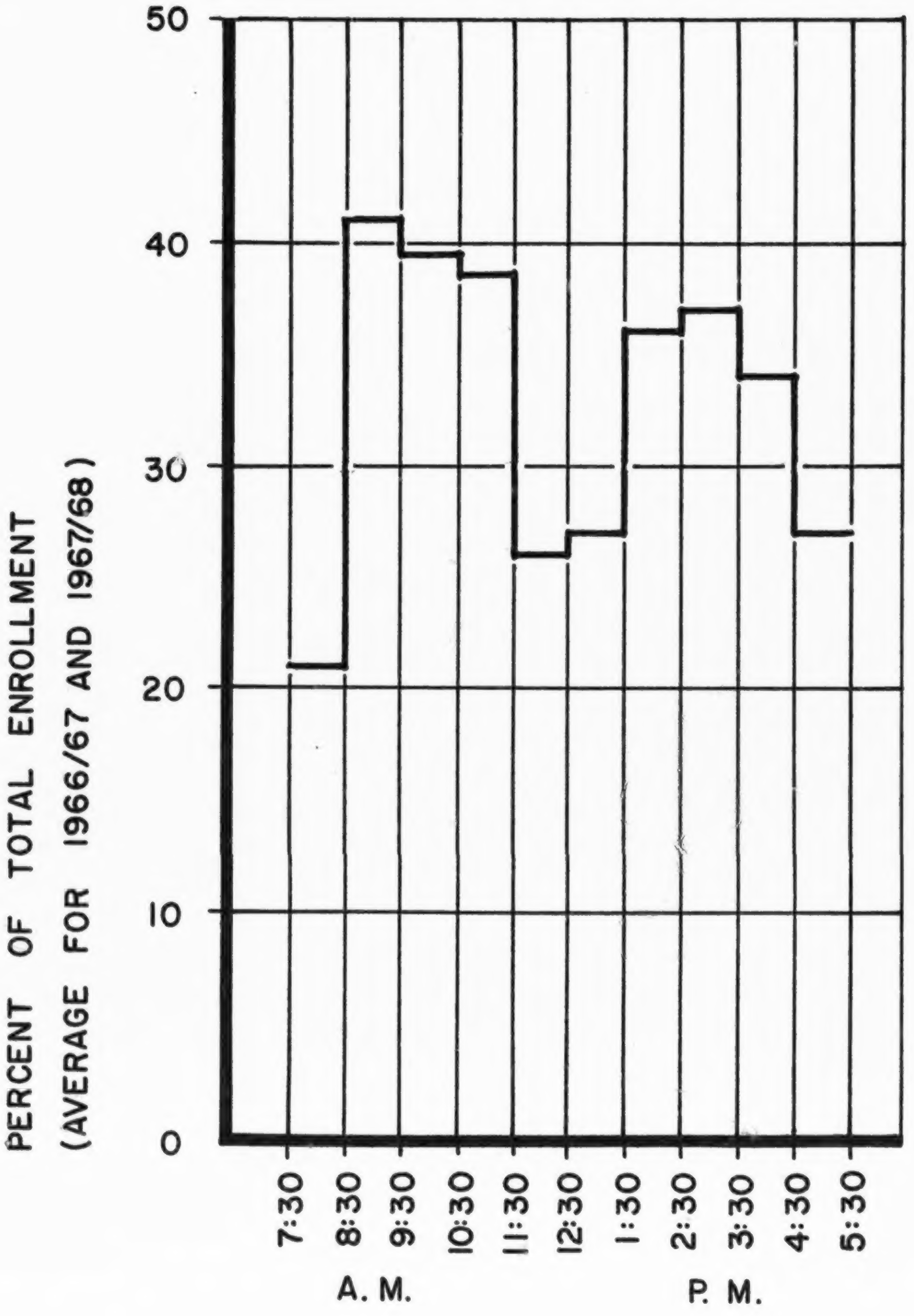

FIGURE 7 - PERCENTAGES OF STUDENTS IN SCHEDULED FACILITIES IN THE ACADEMIC ZONE AT DIFFERENT HOURS ON AN AVERAGE WEEKDAY

on an average weekday. For both types of facilities, students represented the greatest majority of users. Having established the past trends concerning the two above use characteristics, the expected future use characteristics were projected assuming that the same trends will continue. No conclusive data could be obtained about the percentages of graduate students present in their offices in the academic zone at any one time. It was thus assumed that, for both the present and the future, about 30 percent of the non-staff graduate students are present in their offices on the morning hours of an average weekday. The results of the above outlined analyses are summarized in Table 1. The table gives both the existing and the future percentages of students using different facilities in the academic zone at different hours on an average weekday.

Staff and Visitors. Because of the regular work hours during which the majority of staff members are expected to be present in the academic zone, the temporal distribution of staff becomes virtually meaningless from the standpoint of this study. Also, because visitors represent only a small fraction of the campus population and because of the unpredictable nature of their temporal concentrations in the academic zone, their daytime population was not considered. For these two groups (staff and visitors), the only estimates of interest were those related to future parking demands in the academic zone. These estimates are discussed later

Table 1. Students' Daytime Population in the Academic Zone - Existing and Future.

Hours	Students using facilities in the academic zone expressed as percentages of the total enrollment					
	Existing (for an enrollment of 23,370 students in 1967)			Future (for an ultimate enrollment of 35,000 students)		
	scheduled facilities	non-scheduled facilities	total in the academic zone	scheduled facilities	non-scheduled facilities	total in the academic zone
8:00 a.m.	21.0	5.0	26.0	21.0	6.0	27.0
9:00 a.m.	41.0	8.3	49.3	41.0	11.0	52.0
10:00 a.m.	39.5	11.3	50.8	39.5	14.5	54.0
11:00 a.m.	38.5	11.8	50.3	38.5	15.0	53.5
12:00 noon	26.0	12.3	38.3	26.0	15.0	41.0
1:00 p.m.	27.0	9.0	36.0	27.0	12.0	39.0
2:00 p.m.	36.0	10.0	46.0	36.0	13.0	49.0
3:00 p.m.	37.0	13.0	50.0	37.0	16.6	53.6
4:00 p.m.	34.0	11.2	45.2	34.0	15.0	49.0
5:00 p.m.	27.0	5.0	32.0	27.0	6.0	33.0

in this chapter.

Student Auto Trips. Student parking demand is generally dependent on the ratio of home based student auto trips (auto trips times occupancy rate) to student trips by all modes to the academic zone. Conceptually, this ratio may be expected to vary in relationship to income, automobile ownership, trip length, availability of parking, and probably climate. Under conditions of relative constant availability of parking around the academic zone, trip length appears to be the main factor influencing the student's decision to use or not to use his automobile to commute from home to the academic zone. It is conceivable that below a certain minimum trip length, no student auto trips would be made and above a certain maximum trip length, all trips would be made by the automobile. Between these minimum and maximum trip lengths, the ratio of student auto trips to student trips by all modes will vary according to trip length. The relationship between trip length and the percentage of home based student auto trips to the academic zone is particularly useful in student parking demand forecasting models. However, to establish such a relationship quantitatively, elaborate origin-destination data would be needed.

In this study, and for the purpose of developing a student parking demand forecasting model, a simplified technique based on the observed relationship between trip length and the number of home based student auto trips per student (to all destinations including the academic zone) was used. The following is a brief discussion of the procedure applied to establish this relationship. The development of the forecasting model itself is discussed later in this chapter.

Home based student auto trips were examined in seventeen university residence facilities located at varying distances from the academic zone and housing different student subgroups (graduates, undergraduates, single, and married). For each of the examined facilities, the following data were obtained:

N = the total number of students living in the facility.

D = its distance (the actual walking path) from the focal point in the academic zone.

P_1 = the number of automobiles parked at 6:00 a.m. in the parking spaces assigned to the facility (or obviously used by its residents).*

P_2 = the number of automobiles parked at 10:00 a.m. in the parking spaces assigned to the facility (or obviously used by its residents).

P_3 = the number of automobiles parked in the parking spaces assigned to married student apartments (in the facilities to which this item applies) at 8:30 a.m. on a day when the university was in session but classes were not.

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* P_1 was not obtained for facilities housing married students.

K = average occupancy rate of automobiles leaving the facility.

The choice of 10:00 a.m. to observe the number of automobiles left in the parking lots (P_2) was made on the basis of previous parking studies on the Lafayette campus which indicated that the peak parking in and near the academic zone occurred at this hour (10:00 a.m.) (20).

For facilities housing single students, the total number of auto trips made from the facility to all destinations up to 10:00 a.m. = $P_1 - P_2$. The number of student auto trips per resident student (to all destinations) up to 10:00 a.m. $= \frac{K(P_1 - P_2)}{N}$.

For facilities housing married students, the number of student auto trips per resident (to all destinations) up to 10:00 a.m. $= \frac{K[(P_1 - P_2) - (P_1 - P_3)]}{N}$ or $= \frac{K(P_3 - P_2)}{N}$ where $P_1 - P_3$ is the number of auto trips performed by non-students (wives or other relatives), most probably work trips.

With this information obtained for each of the examined facilities, a relationship was established between the number of student auto trips per resident student (to all destinations) up to 10:00 a.m. and the trip length from the facility to the focal point in the academic zone.

The seventeen observations were fitted by the "least squares" method. The equation resulting was as follows:

$$Y = 1.045 \times 10^{-8} L^2 - 0.067 \quad \text{for } L \leq 10{,}105 \text{ and } \geq 2{,}523 \text{ feet}$$

where:

Y = the number of student auto trips per resident student to all destinations up to 10:00 a.m. and,

L = the distance (in feet) between the residence and the focal point in the academic zone (referred to later as trip length).

Figure 8 shows the number of student auto trips per resident student (to all destinations) up to 10:00 a.m. in relation to trip length.

In this equation, the high coefficient of multiple determination ($R^2 = 0.93$) confirmed the assumption that the student's decision to use or not to use his automobile to the academic zone is greatly influenced by the distance at which he lives from the academic zone. As such, the observed relationship is not expected to change significantly in the future. It was thus used as a basis for developing a student parking demand forecasting model. This was done on the assumption that the relative parking availability in and near the academic zone will remain virtually the same as now for the future.

Residential Distribution of Students. Two characteristics related to the residential distribution of students were analyzed.

1. The proportions of students using different kinds of residential facilities (university housing, fraternity and sorority houses, cooperatives, and community housing).

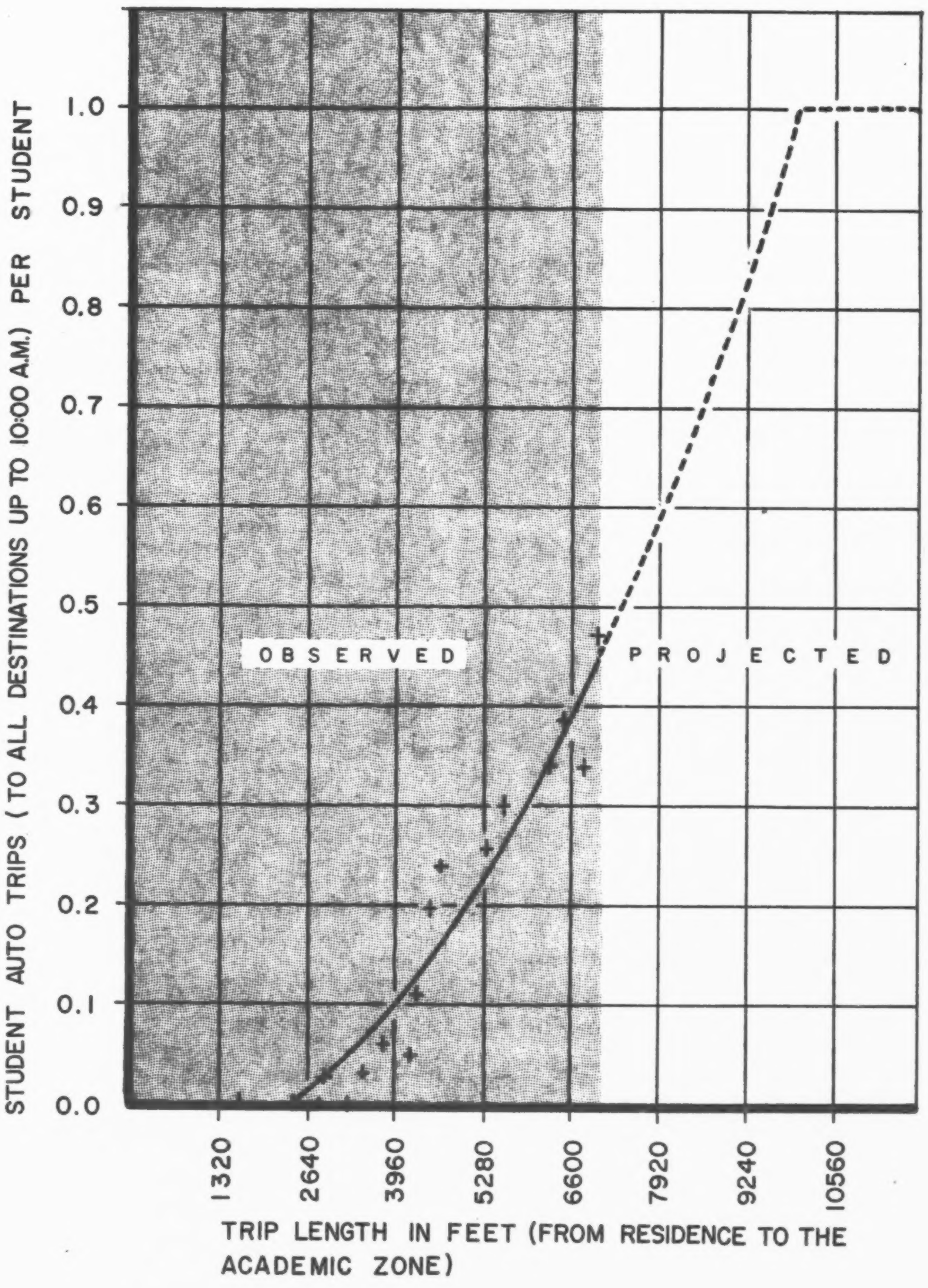


FIGURE 8 – STUDENT AUTO TRIPS PER STUDENT BY TRIP LENGTH

2. The proportions of students living at different distances from the academic zone.

The population of students was classified into six subgroups: graduate single men, graduate single women, graduate married students, undergraduate single men, undergraduate single women, and undergraduate married students. This classification permits testing the hypotheses that sex, educational level, and marital status influence the student residential distribution. It is also useful in forecasting future changes in such residential distribution since the prospective numbers of students in each of these subgroups can easily be forecasted.

Students' Choice of Residential Facilities. In analyzing the percentages of students using different kinds of residential facilities, data on the entire population of students for 1967/68 were used. Figure 9 shows the existing university residential facilities, fraternities, sororities, and cooperative houses. Data on the number of students residing in these facilities and on the total enrollment by student subgroups were obtained (21,11). The percentage of students belonging to each subgroup and residing in each kind of facility was established. Table 2 summarizes the findings and Figure 10 illustrates them. Both educational level and marital status show strong correlations with the choice of the kind of housing facility. On the basis of these observed percentages, the future percentages of students expected to

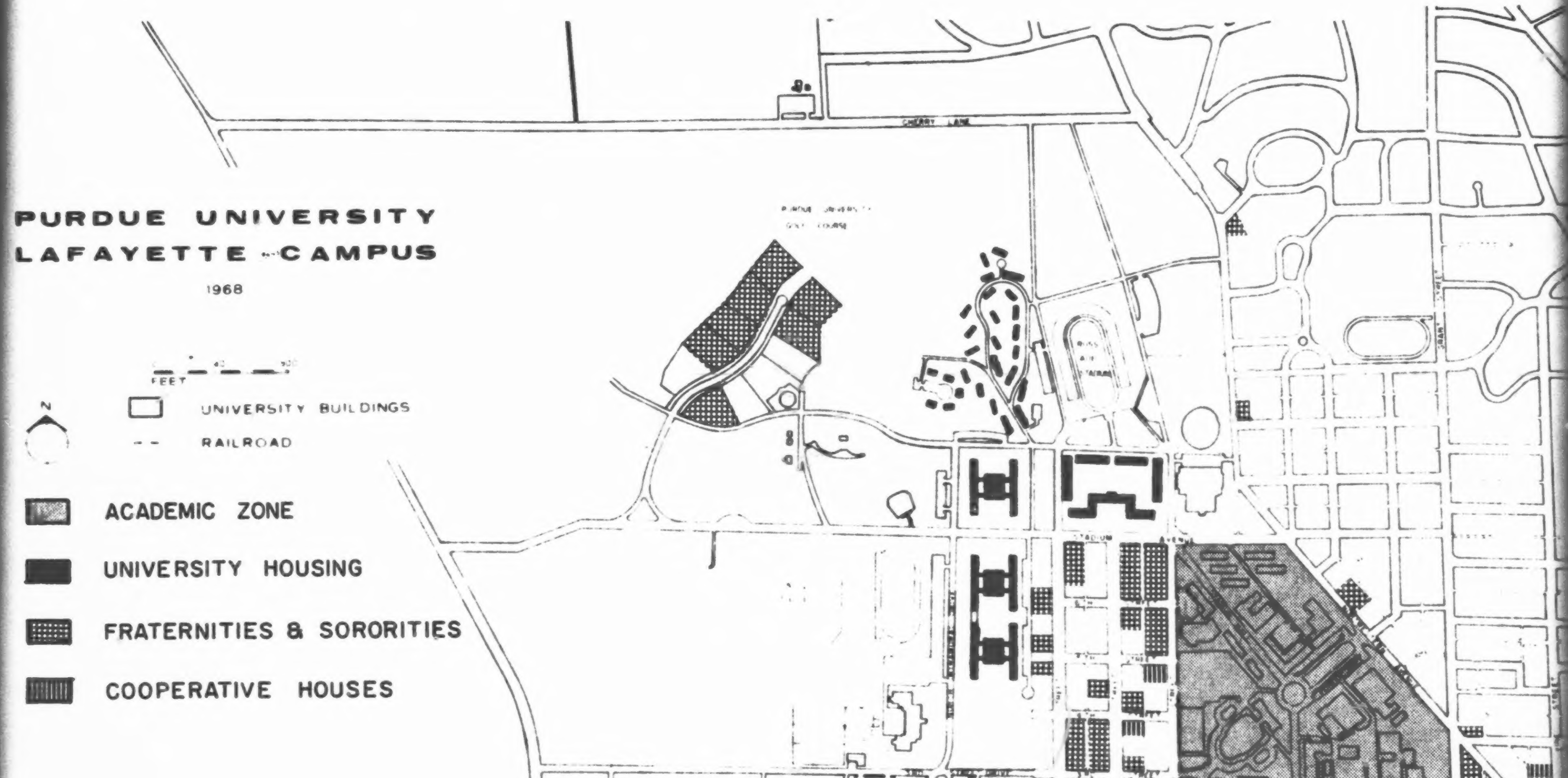
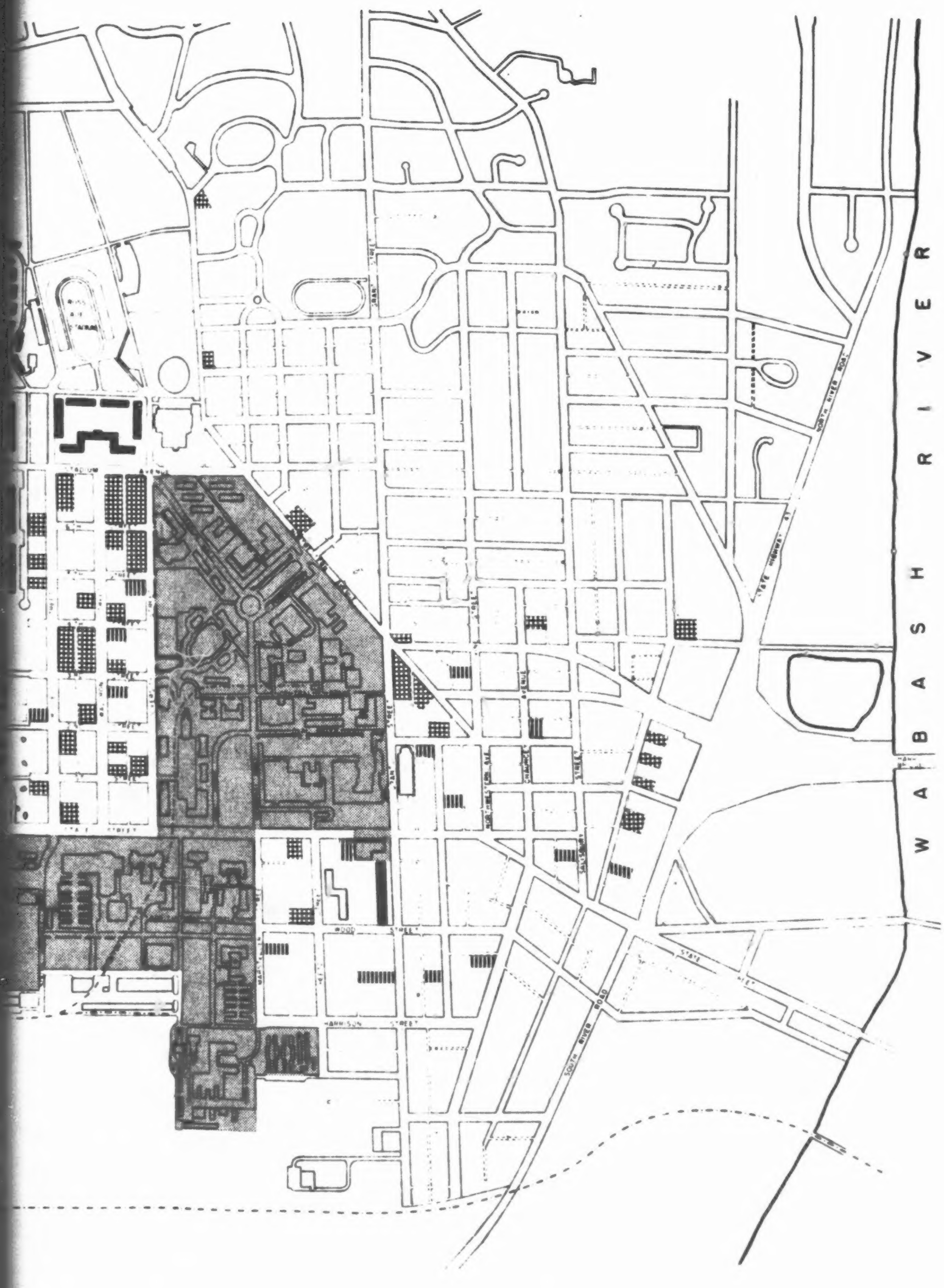

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
FEET
N
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
UNIVERSITY HOUSING
FRATERNITIES & SORORITIES
COOPERATIVE HOUSES
CHERRY LANE
PURDUE UNIVERSITY GOLF COURSE
STADIUM AVENUE
STATE HIGHWAY 26
HARRISON STREET

FIGURE 9 - EXISTING STUDENT HOUSING FACILITIES (OTHER THAN COMMUNI


STADIUM AVENUE
NORTH RIVER ROAD
STATE HIGHWAY 43
NORTHWESTERN AVE
CHAUNCEY
SALISBURY
STATE STREET
WOOD STREET
HARRISON STREET
SOUTH RIVER ROAD
WABASH RIVER

IES (OTHER THAN COMMUNITY HOUSING)

Table 2. Existing Distribution of Students in the Different Kinds of Available Housing Facilities.

Student Subgroups		Numbers and percentages of students living in different kinds of housing facilities				Student enrollment (by student subgroups)	Percent of the total student enrollment
		University housing	Greek-letter Organizations	Cooperative houses	Community housing		
Graduate married	number	926	--	--	1,839	2,765	11.8
	percent*	33.5	--	--	66.5	100.0	
Undegraduate married	number	841	--	--	991	1,832	7.8
	percent	46.0	--	--	54.0	100.0	
Graduate single men	number	450	--	--	1,503	1,953	8.4
	percent	23.0	--	--	77.0	100.0	
Graduate single women	number	200	--	--	353	553	2.4
	percent	36.0	--	--	64.0	100.0	
Undergraduate single men	number	5,309	2,154	319	3,373	11,155	47.7
	percent	47.6	19.3	2.9	30.2	100.0	
Undergraduate single women	number	2,953	906	141	1,112	5,112	21.9
	percent	57.8	17.7	2.8	21.7	100.0	
Total Students	number	10,679	3,060	460	9,171	23,370	100.0
	percent	46.0	13.0	2.0	39.0	100.0	

* Percentages of the total enrollment in the subgroup.

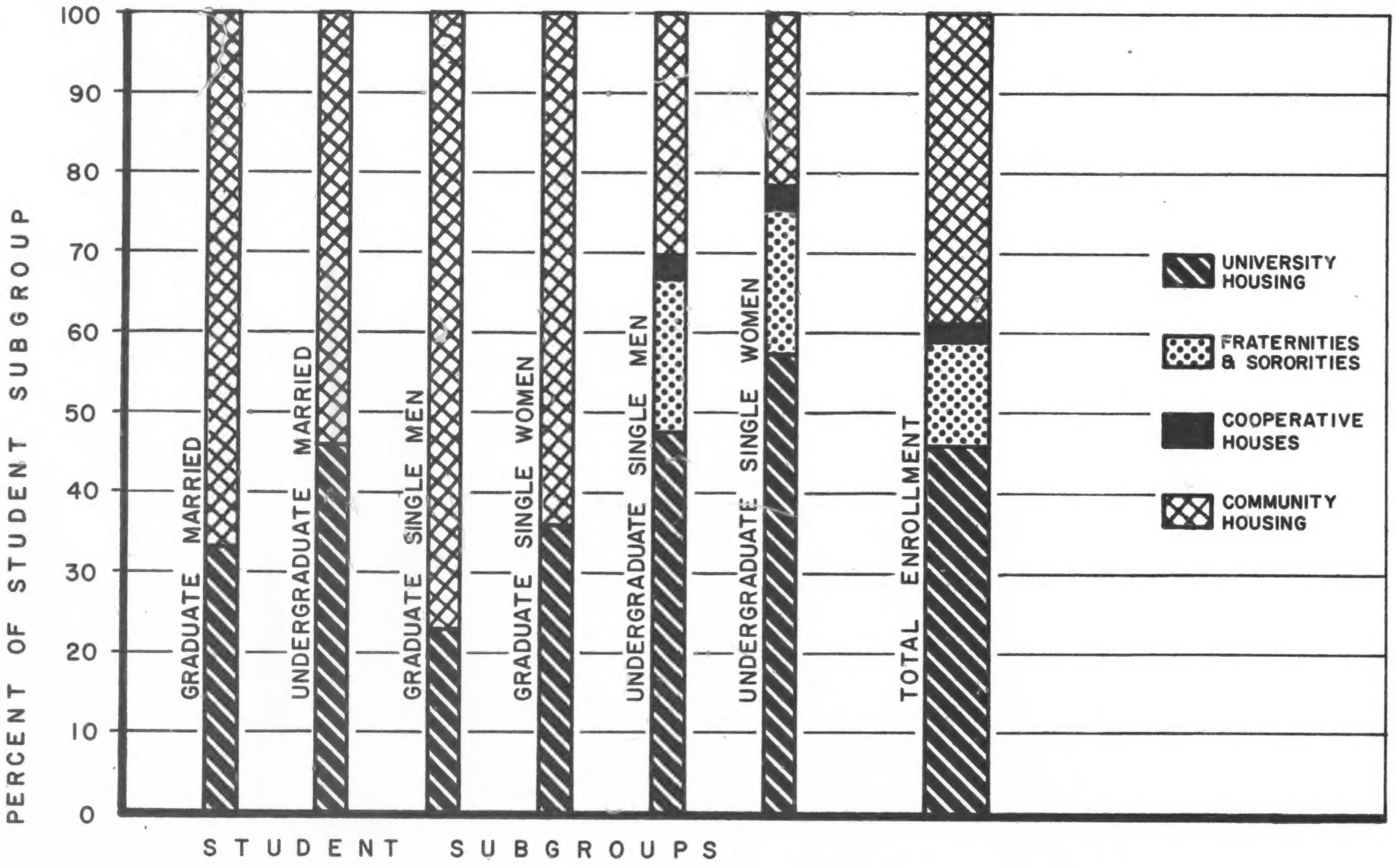


FIGURE 10 – PERCENTAGES OF STUDENTS LIVING IN DIFFERENT KINDS OF HOUSING FACILITIES BY STUDENT SUBGROUP, FALL 1967

live in different kinds of residential facilities were estimated. Both university housing policy and the students potential demand on university housing were considered. The results of the faculty questionnaire indicated an envisaged increase in the proportions of students housed in university housing facilities (14). During the period 1963-1967 students' demand on university housing facilities tended to increase (22). These facilities appear to offer economic advantages (in rents, maintenance, and proximity to the academic zone) that are difficult to match in community owned housing facilities.

Based on the opinions of faculty members and on the observed trends of student demand on university housing facilities, it was estimated that about 55 percent of the undergraduate single students, 40 percent of the graduate single students, and 40 percent of the married students will be accommodated in university housing facilities in the future.

The Spatial Distribution of Student Residences. As noted previously, the number of student auto trips is highly correlated with the distances at which students live from the academic zone. As such, the spatial distribution of student residences becomes meaningful from the standpoint of campus transportation planning. The following is an analysis of the spatial distribution of the student residences around the academic zone. The primary purpose of the analysis is to examine the existing and estimate the future proportions of students living at different distances from the academic zone.

Because the composition of the population of students is expected to change in the future, the analysis of the spatial distribution of the student residences should test whether or not future changes in the student population composition would cause changes in the proportions of students living at different distances from the academic zone. In other words, the analysis should test, for each student subgroup (graduates, undergraduates, single, married...etc.), whether or not the proportions of students living at different distances from the academic zone are significantly different from those of other subgroups. Subgroups that show significant differences should, then, be analyzed separately while others can be lumped together. This analysis was performed in two steps:

1. A number of relevant student population subgroups were first tested, in pairs, for significance of differences in the mean distances at which students live from the academic zone and in the variances of these distances from the means. Statistically, subgroups, which have significantly different means and variances should also have significantly different proportions of students living at different distances from the academic zone. Moreover, testing for means and variances is much more reliable

and requires relatively smaller sample sizes. By this step, therefore, significantly different subgroups were identified.

2. For each of the identified subgroups, the existing percentages of students living at different distances from the academic zone were statistically estimated and the future percentages then forecasted.

To identify student population subgroups living at significantly different distances from the academic zone (in terms of means and variances) a pilot study on a small sample of students was first undertaken. The preliminary results of this pilot study suggested further testing of five student subgroups: graduate single, graduate married, undergraduate single men, undergraduate single women, and undergraduate married students. The sizes of statistically representative samples of students of these five subgroups were also determined on the basis of this pilot study. From university records, the data obtained gave the student's status (male, or female, single or married, graduate or undergraduate) and his local address (23). Student addresses were grouped in distance classes (concentric rings around the focal point) with an interval of 0.25 miles. Residences located at distances over four miles from the focal point were not included to avoid distortion of results.

For each of the five subgroups, the means and variances (of the distances of residences from the focal point) were obtained and tested, in pairs, for significance of difference. Both the mean and variance of the distance at which single students live (both graduate and undergraduates) were found to be significantly different (on the 0.05 α level) from those for married students (both graduates and undergraduates). No other significant differences were found. Accordingly, for each of these two subgroups, the existing proportions of students living at different distances from the academic zone were statistically estimated. The student addresses were grouped in distance classes with an interval of 0.50 miles (actual walking distance zones). Figure 11 shows the boundaries of these zones. The range of distances covered in the analysis and the class interval used were set on the basis of the observed numbers of student auto trips discussed earlier.

The size of a statistically representative sample of students was set according to maximum allowable estimation errors of ± 2 percent for single students and ± 3 percent for married students. By plotting the student addresses (in Spring 1967) on a map, the numbers (and thus the percentages) of residences falling in each distance zone were obtained. The results were tabulated by student subgroup, by distance zone, and by kind of residence facility. Table 3 shows the existing percentates of students living in different kinds of housing facilities at different distances from the academic zone for single students and married students. Figure 12 shows the existing cumulative "less than"

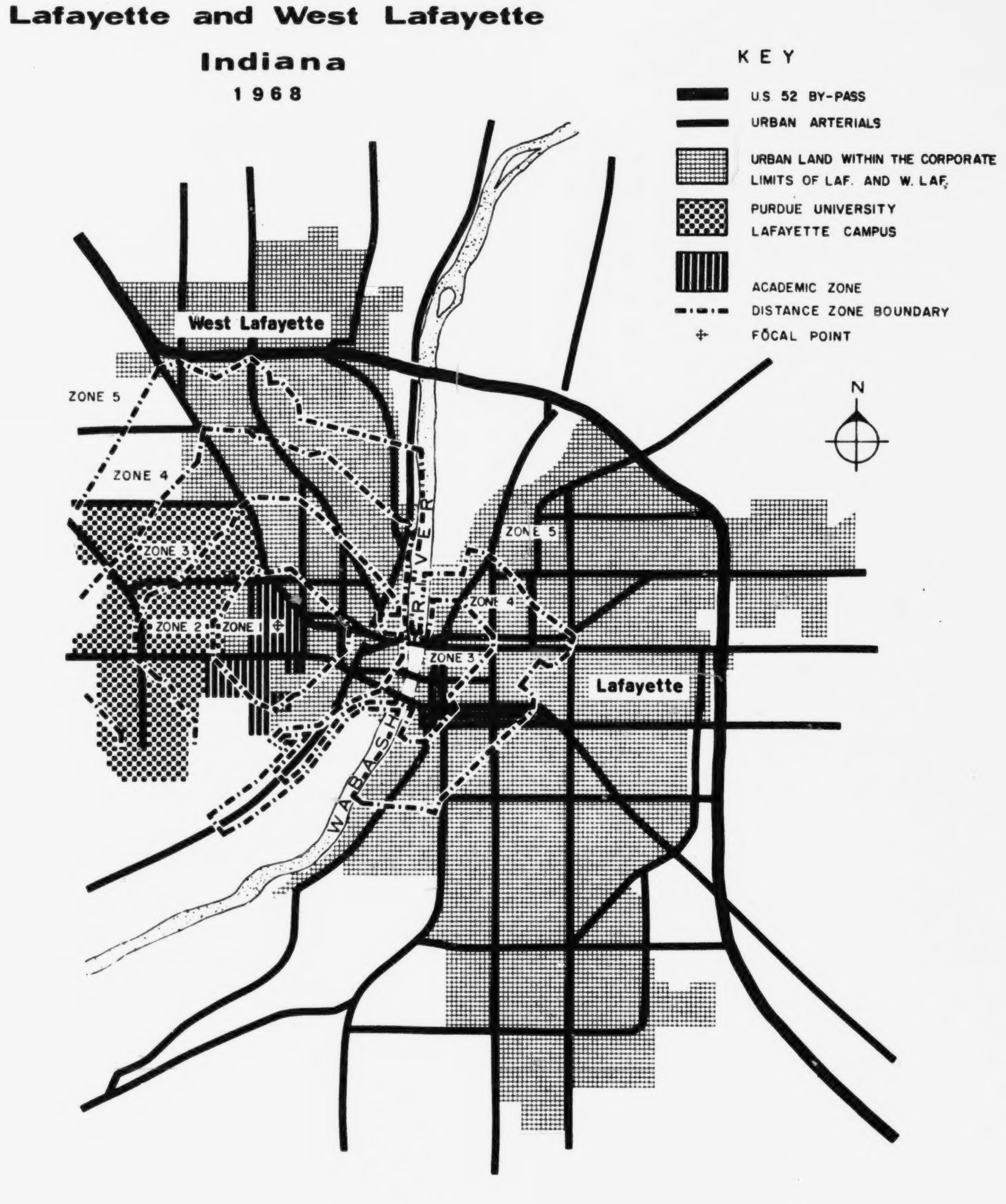

Lafayette and West Lafayette
Indiana
1968
KEY
U.S. 52 BY-PASS
URBAN ARTERIALS
URBAN LAND WITHIN THE CORPORATE LIMITS OF LAF. AND W. LAF.
PURDUE UNIVERSITY LAFAYETTE CAMPUS
ACADEMIC ZONE
DISTANCE ZONE BOUNDARY
FOCAL POINT
N
West Lafayette
Lafayette
ZONE 5
ZONE 4
ZONE 3
ZONE 2
ZONE 1
ZONE 5
ZONE 4
ZONE 3
WABASH RIVER

FIGURE II - RESIDENTIAL DISTRIBUTION OF STUDENTS - DISTANCE ZONES

Table 3. Existing Percentages of Students Living in Different Kinds of Housing Facilities at Different Distances from the Academic Zone.

Distance from the academic zone (in miles)	Percentages of students living in different kinds of housing facilities							
	Single students					Married students		
	University housing	Greek-letter organizations	Cooperative houses	Community housing	Total	University housing	Community housing	Total
.01 to .50	15.0	11.0	2.0	11.0	39.0	--	8.0	8.0
.51 to 1.00	32.5	3.0	0.5	3.0	39.0	22.5	7.5	30.0
1.01 to 1.50	--	2.0	--	4.5	6.5	15.5	3.0	18.5
1.51 to 2.00	--	--	--	2.5	2.5	--	4.0	4.0
2.01 or more	--	--	--	13.0	13.0	--	39.5	39.5
Total	47.5	16.0	2.5	34.0	100.0	38.0	62.0	100.0

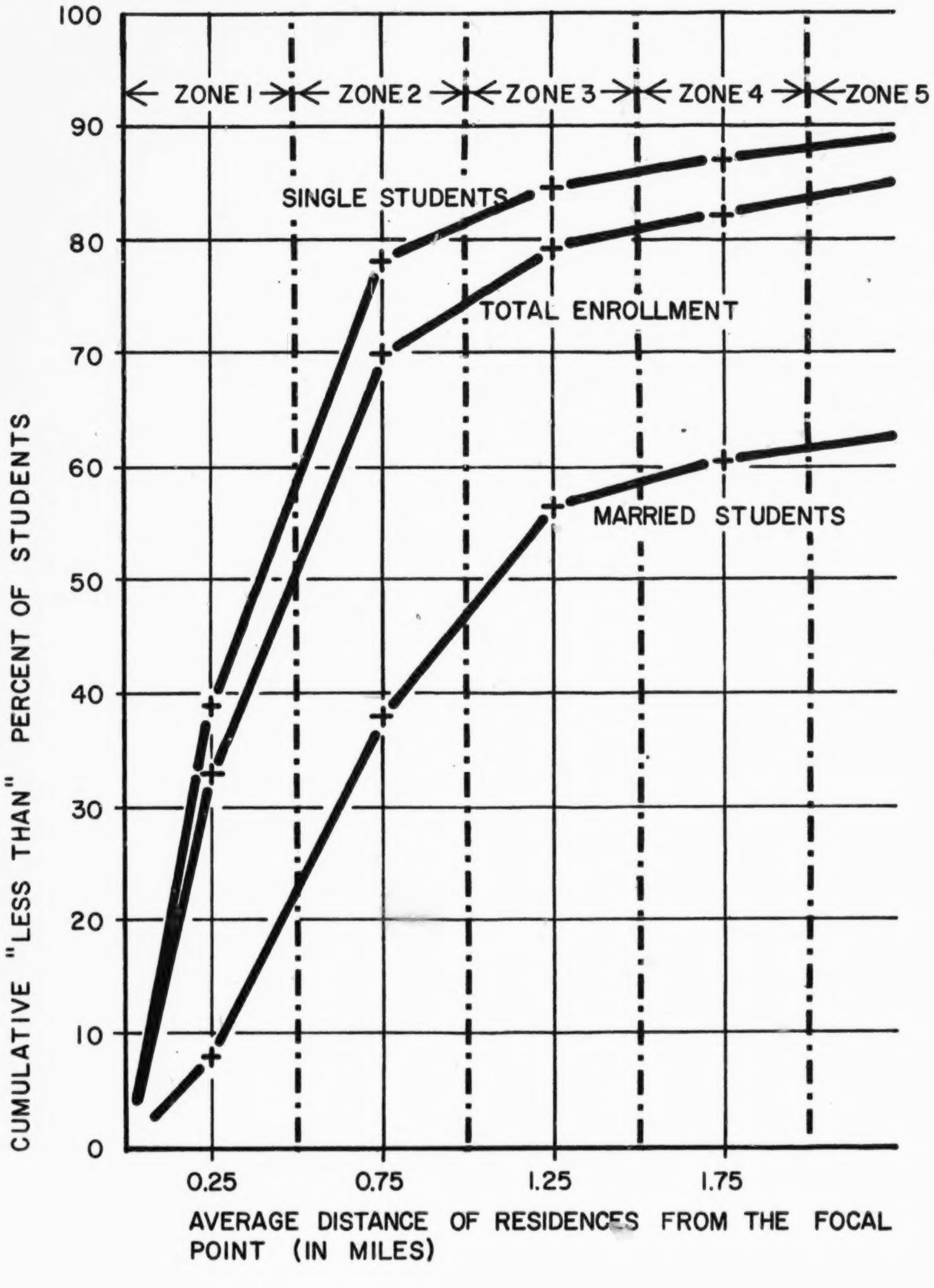


FIGURE 12 – PERCENTAGES OF STUDENTS LIVING AT DIFFERENT DISTANCES FROM THE ACADEMIC ZONE, SPRING 1967

proportions of students living at different distances from the academic zone for single students, married students, and all students.

About 13 percent of the single students and about 39.5 percent of the married students live at distances over two miles. As expected, the percentage of single students living distant from the academic zone is much less than that of the married students. Single students neither have the need for suburban spacious living nor are willing to sacrifice the proximity to the intense social interactions on and around the academic zone. High concentrations of both single and married students occur within one mile from the academic zone. This is obviously due to the fact that all university housing facilities are located within this range of distance. About 46 percent of the students living in this range live in university facilities. The remaining proportion indicates an undebatable trend of students to live close to the academic zone even if they live in non-university facilities.

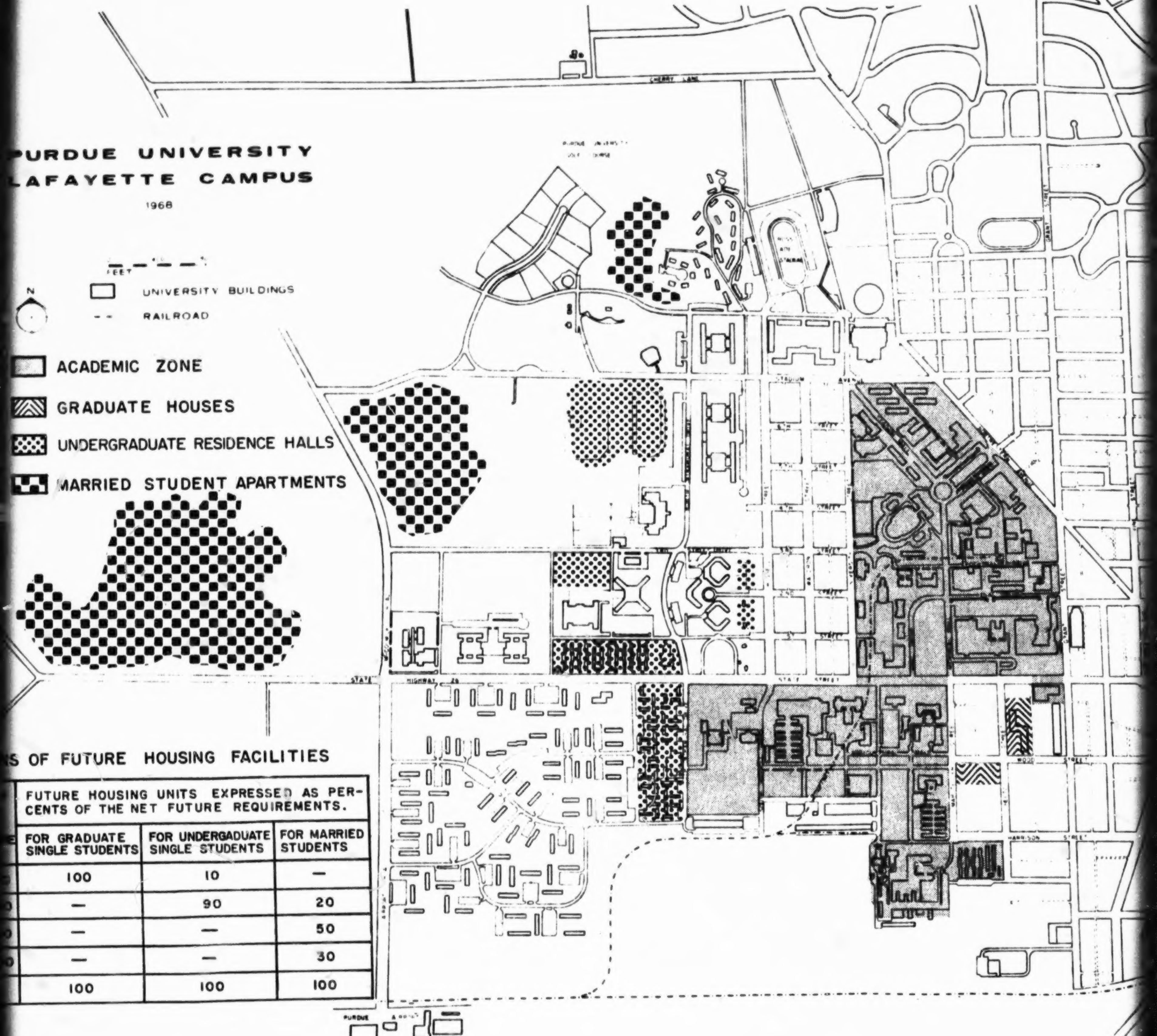
These findings and observations provide the basis for estimating the future distribution of student residences. This was estimated on the basis of three main residential aspects:

1. The estimates of future numbers of students living in different kinds of housing facilities.

2. The expected future locations of the different kinds of housing facilities.
3. The existing proportions of students living at different distances from the academic zone.

The first and third aspects have already been discussed. The following is a discussion of the second aspect; the expected locations of the different kinds of housing facilities.

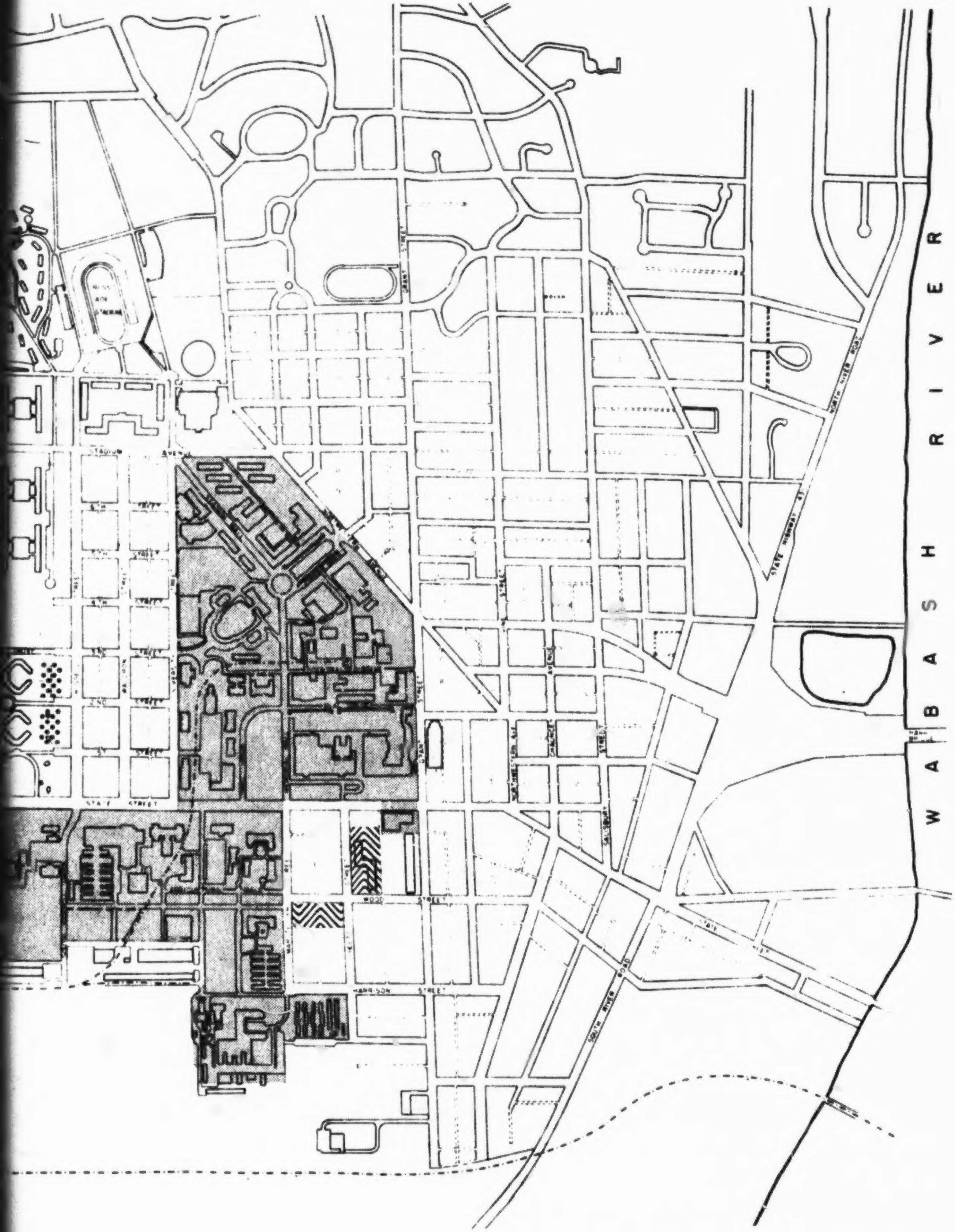
Future Greek-letter organizations and cooperative houses are expected to be provided at approximately their present distances from the academic zone. Additional community housing facilities are apt to be provided at distances between 1.5 and 2.5 miles. Little room for expansion at closer distances is available for these facilities. The future locations of university housing facilities are subject to different probable policies. A number of possible alternative layouts of future university housing facilities (based on the existing standards of land coverage and building heights) were developed and examined to determine which would provide maximum future advantages. The layout in which the future housing facilities were most closely located in relation to the academic zone and which still provided flexibility in future land uses was chosen. Figure 13 shows the assumed locations of future university housing facilities. Accordingly, the future proportions of students living at different distances from the academic zone were estimated.


PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
FEET
N
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
GRADUATE HOUSES
UNDERGRADUATE RESIDENCE HALLS
MARRIED STUDENT APARTMENTS
CHERRY LANE
STADIUM AVENUE
STATE STREET
STATE HIGHWAY 26
WOOD STREET
HARRISON STREET
PURDUE

S OF FUTURE HOUSING FACILITIES

FUTURE HOUSING UNITS EXPRESSED AS PERCENTS OF THE NET FUTURE REQUIREMENTS.		
FOR GRADUATE SINGLE STUDENTS	FOR UNDERGADUATE SINGLE STUDENTS	FOR MARRIED STUDENTS
100	10	—
—	90	20
—	—	50
—	—	30
100	100	100

E 13 — PROBABLE LOCATIONS OF FUTURE UNIVERSITY HOUSING FACILITIES


WABASH RIVER
STADIUM AVENUE
STATE STREET
WOOD STREET
HARRISON STREET
GRANT STREET
NORTHWESTERN AVE
CHAUNCEY AVENUE
SALISBURY STREET
STATE HIGHWAY 43
NORTH RIVER ROAD
SOUTH RIVER ROAD

VERSITY HOUSING FACILITIES

Table 4 shows the estimated future percentages of students living in different kinds of housing facilities at different distances from the academic zone.

Future Commuting Demands

Four campus population characteristics influencing present and future trip productions and trip modes to and from the academic zone have been discussed. In this section, the future demand for commuting to and from the academic zone will be estimated. The magnitude of this demand depends on the size and composition of the campus population and the daytime population in the academic zone. The choice of transportation modes in commuting depends on the patterns of student auto trip productions, on the residential distribution of students, and on the available alternative modes of transportation. Three alternative modes of commuting will be examined: (1) by automobile from residence to parking facilities around the academic zone, (2) by buses either from residence or from remote parking facilities to the academic zone, and (3) on foot.

The importance of considering traffic volumes on the street network surrounding the academic zone and caused by commuting is recognized. In this study, however, the discussion of this aspect is limited to a subjective evaluation of the effects on traffic volumes on the network of some alternative locations, types, and capacities of future university parking facilities in and around the academic zone. To

Table 4. Estimated Future Percentages of Students Living in Different Kinds of Housing Facilities at Different Distances from the Academic Zone.

Distance from the academic zone (in miles)	Percentages of students living in different kinds of housing facilities							
	Single students					Married students		
	University housing	Greek-letter organizations	Cooperative houses	Community housing	Total	University housing	Community housing	Total
.01 to .50	14.0	9.6	1.7	7.5	32.8	--	4.0	4.0
.51 to 1.00	37.7	3.4	0.8	2.8	44.7	14.8	7.0	21.8
1.01 to 1.50	--	3.0	--	4.0	7.0	18.4	3.0	21.4
1.51 to 2.00	--	--	--	2.5	2.5	6.8	6.0	12.8
2.01 or more	--	--	--	13.0	13.0	--	40.0	40.0
Total	51.7	16.0	2.5	29.8	100.0	40.0	60.0	100.0

obtain reliable estimates of future average traffic volumes on the street network surrounding the academic zone would require a multiplicity of other input data (other than future locations, types, and capacities of university parking facilities) that are beyond the scope of this study.

Future Parking Demands. In 1968, a total number of about 5630 off-street parking spaces (in and around the academic zone) were provided and operated by the university. The majority of these spaces are provided for full-time staff members. A relatively limited number of spaces are assigned to commuter students and visitors. Besides, on-street free parking is available around the academic zone. For the future, the relative availability of parking was assumed to remain virtually unchanged. The future parking demands were estimated accordingly. Demands by students, staff, and visitors were estimated separately.

Students. The relationship between trip length (from residence to the academic zone) and the number of student auto trips per resident student (to all destinations) up to 10:00 a.m. was established earlier. Based on this relationdeship, a students' parking demand forecasting model was developed. The total number of student automobiles actually parked around the academic zone at 10:00 a.m. on an average week day was assumed representative of the student parking demand.*

Let:

i = zones of different ranges of trip lengths where $i = 1, 2, \ldots, 5$ (see Figure 11).

A_i = total number of student auto trips from zone i to all destinations up to 10:00 a.m.

Z_i = total number of student auto trips from zone i to the academic zone up to 10:00 a.m.

M_i = total number of student trips by all modes from zone i to the academic zone up to 10:00 a.m.

L_i = average trip length from residences in zone i to the focal point in the academic zone (in feet).

N_i = total number of students living in zone i .

K_i = average auto occupancy rate for trips from residences in zone i to the academic zone.**

C = percent of students living in zone i and expected to be present in the academic zone up to 10:00 a.m. "C" is assumed constant for all values of i since the master schedule of the university on the basis of which student class schedules are determined

---

* The area referred to as "around the academic zone" is that used in a study on future traffic facilities for the Lafayette campus and includes three rows of blocks around the academic zone (20).

** For married students, average auto occupancy was estimated to be 1.1 students per auto for all zones. For single students, average auto occupancy was estimated to be 2.5 for zone 2 and was accordingly assumed to be 2.2, 1.8, and 1.3 students per auto for zones 3, 4 and 5 respectively.

(and hence the hours at which they should be present in the academic zone) is not "biased" by marital status (and thus not "biased" by distance of residence).

T_i = number of student auto trips to the academic zone per student trip by all modes to the academic zone up to 10:00 a.m.

therefore

$$T_i = \frac{Z_i}{M_i}$$

In terms of A_i and N_i, this can be expressed as follows:

$$T_i = \frac{A_i}{N_i} \times \frac{\frac{Z_i}{A_i}}{\frac{M_i}{N_i}}$$

but $\frac{A_i}{N_i} = Y_i$ = number of sutdent auto trips per resident student (in zone i) to all destinations up to 10:00 a.m.

therefore

$$T_i = Y_i \cdot q_i$$

where

$$q_i = \frac{\frac{Z_i}{A_i}}{\frac{M_i}{N_i}} = \frac{\frac{Z_i}{M_i}}{\frac{A_i}{N_i}}$$

It can be shown mathematically that if Z_i is equal to A_i, q is independent of i. In this case, it can be safely assumed that $Z_i = A_i$ since the great majority of student auto trips up to 10:00 a.m. are expected to end around the academic zone. Therefore, q is assumed constant for all values of i.

If P_s is the total number of student automobiles parked around the academic zone at 10:00 a.m. on an average weekday, then

$$P_s = \sum_{i=1}^{5} C \cdot N_i \cdot \frac{T_i}{K_i} = \sum_{i=1}^{5} C \cdot N_i \cdot \frac{Y_i \times q}{K_i}$$

or

$$P_s = C \cdot q \cdot \sum_{i=1}^{5} \frac{N_i\ Y_i}{K_i}$$

but Y_i has previously been shown to have the following value:

$$Y_i = 1.045 \times 10^{-8} L^2 - 0.067 \quad \text{for } L \leq 10{,}105 \text{ and } \geq 2{,}523 \text{ feet}$$

In this model, the future values of the independent variables (C, N_i, Y_i) were estimated earlier in the discussion of the population characteristics influencing commuting. "C" was estimated from the analysis of the student daytime population in the academic zone, N_i was estimated from the analysis of the student residential distribution, and Y_i was established by direct observation. Values of K_i for zone 2 (for single and married students) were estimated by direct observation while those for zones 3 through 5 were subjectively assumed accordingly.

To establish the value of the constant q in this model, the result of an actual count of student automobiles parked around the academic zone at 10:00 a.m. in the Spring of 1968 (1650 automobiles) was used for calibration (20). The value of q was found to be equal to 0.7. The accuracy of the model was then tested by comparing the total number of student automobiles parked around the academic zone at 10:00 a.m. in the Spring of 1962 as obtained by an actual count and as replicated by the model. The actual count in 1962 was 1150 automobiles while the total as replicated by the model was 1077 automobiles. The error is acceptable for the purpose of this study.

Accordingly, for the ultimate enrollment, the future student peak parking demand (at 10:00 a.m.) is estimated to be about 3,316 parking spaces. This estimate was increased to 3,685 parking spaces since only 90 percent of available parking spaces can be used efficiently during periods of peak parking demand. Of these, about 600 parking spaces are expected to be required by students living in university housing facilities (married student residents, McCutcheon Hall, etc.).

Staff and Visitors. At the present time, the university operates sufficient parking for all full-time staff members. It was assumed that this policy will remain unchanged in the future. To estimate future staff parking demand, a relationship was established, on the basis of data obtained from university records for the years 1963 through 1967, between the number of staff parking spaces provided by the university in the academic zone and the total number of full-time staff members working there (20). Knowing that the number of staff parking spaces provided in these past years by the university in the academic zone proved adequate, the established relationship was thus used to estimate the future staff parking demand.

In establishing this relationship, the ratio of the number of full-time staff members working in the academic zone to the total number of full-time staff members (on the whole campus) was determined for 1962 and assumed constant in the future.* Figure 14 shows the observed and projected relationship between the number of staff parking spaces provided by the university in the academic zone and the number of full-time staff members working there. In this figure, the observations obtained for the five past years (1963 through 1967) were fitted by using the "least squares" method. The resulting straight line relationship was:

$$P_F = 1.17\ F_a - 2958.7 \quad (R^2 = 0.96)$$

where P_F = number of staff parking spaces provided in the academic zone (including an allowance of 10 percent for peak hour vacancies), and

F_a = number of full-time staff members working in the academic zone.

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* Data were not available for any other years.

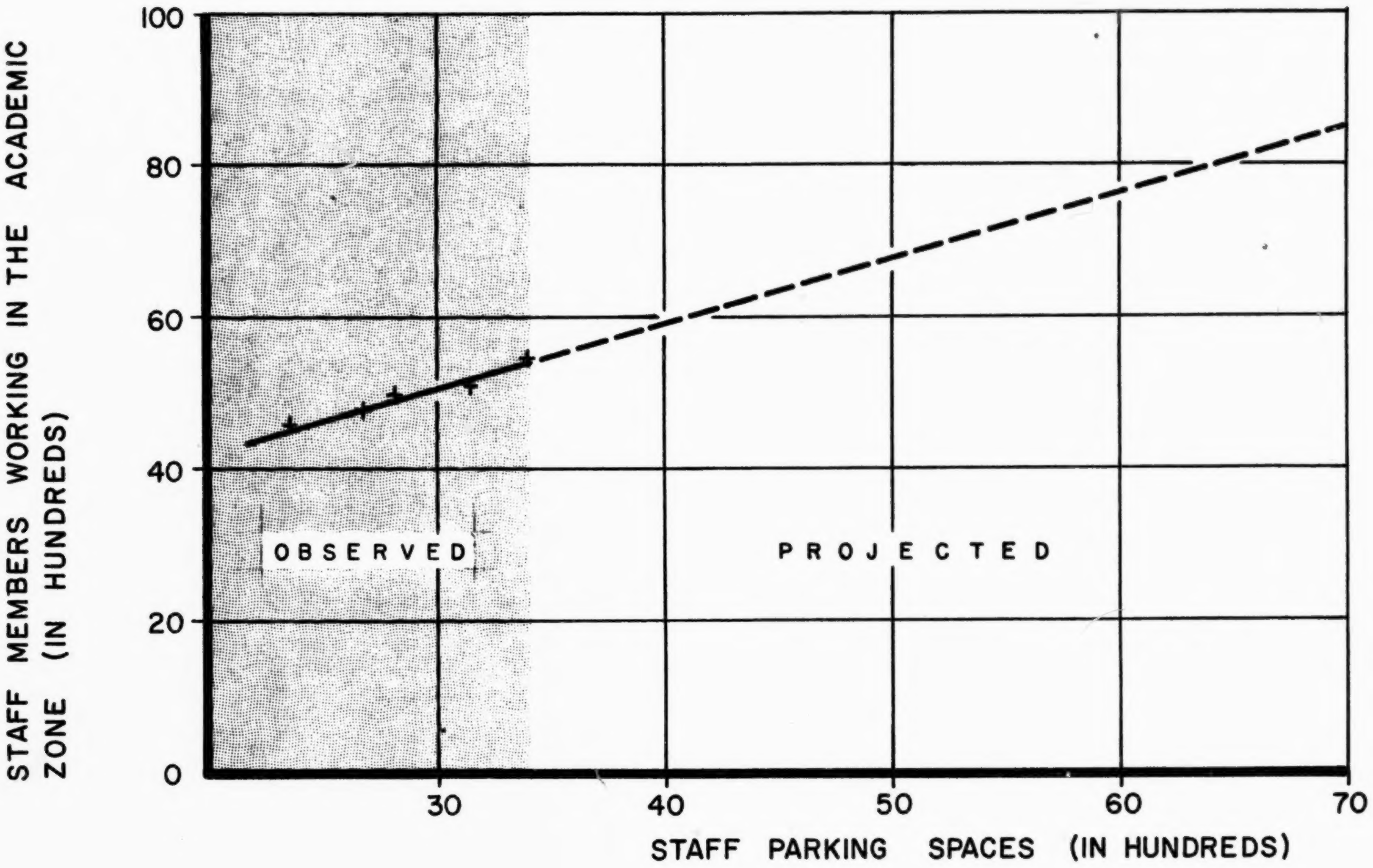

FIGURE 14 – NUMBER OF STAFF PARKING SPACES PROVIDED BY THE UNIVERSITY PER STAFF MEMBER WORKING IN THE ACADEMIC ZONE, 1963 - 1967

It is recognized that this formula has the limitation of being based on a relatively small number of observations. However, for the purpose of estimating future staff parking demand, the formula gives reasonable accuracy. For the ultimate campus population, about 8,210 staff members are expected to be working in the academic zone (0.87 of the total number of staff members on the campus). Future staff parking demand at ultimate enrollment was thus estimated (on the basis of the established relationship) to be about 6,650 parking spaces.

In estimating future visitor parking demand, the ratio of the number of parking spaces (in the academic zone) used by visitors to that used by staff members was observed for 1965 through 1967. The ratio was found to be about 0.05. It was assumed that, in the future, the university will still provide visitor parking for about 0.05 of the staff parking demand. Thus, the ultimate future visitor parking demand was estimated to be about 330 spaces.

Future Provision of Bus Systems. The future provision of bus systems as an alternative mode of commuting to the academic zone was considered. Buses, if used, should be basically planned to meet student commuting demands. Staff and visitors are not expected to use the system in the periods of peak student loads. Buses can be operated from remote parking facilities and/or university housing facilities to the academic zone and vice versa. They can thus substitute for part of the need for parking around the academic zone and/or commuting by automobile from university housing facilities. As such, the student loads expected on a bus system around a given time depend on the number of student auto trips expected to be made to the academic zone around the same time.

The expected future student load on a bus system was estimated as follows. Of the existing on-street free parking spaces around the academic zone, about 1000 spaces were assumed to remain used in the future. Analysis of the daytime population shows that about 27 percent of the student population are expected to be present in the academic zone at 7:30 a.m. These students are also expected to make about 1658 auto trips to the academic zone shortly before this time. Due to the favorable locations of the parking spaces around the academic zone, these will probably be almost entirely occupied by 7:30 a.m. Remote parking facilities and the bus system (if this combination is provided) will then start to accommodate the overflow. But at 8:30 a.m., 52 percent of the students are expected to be present in the academic zone. If it is assumed that not more than 2 percent of the student population return to their residences after the 7:30 a.m. class, then not more than 27 percent of the student population will have to commute to the academic zone between 7:30 and 8:30 a.m. These will have little choice but to use remote parking facilities and the bus system or to walk. As such, these constitute the probable peak student load on the system since analysis of other daytime populations does not suggest the probability of higher peaks at any one time after 8:30 a.m.*

Accordingly, the expected future number of student auto trips made to the academic zone around 8:30 a.m. was estimated and assumed equal to the expected peak student load on the bus system. This estimate was arrived at by using the student parking demand forecasting model. The value of "C" used in this case was 0.27 (the percent of students expected to commute to the academic zone around 8:30 a.m.). It was thus estimated that if a bus system (or systems) is used, it could have a peak load of 2150 students around 8:30 a.m. Of these, about 430 students are expected to be living in university housing facilities.

Pedestrian Commuting. Most of the pedestrian trips made to the academic zone are generated by university housing facilities and fraternities, sororities, and cooperative houses located in the vicinity of the academic zone. In the future, commuting from these kinds of residential facilities is expected to remain predominantly pedestrian. The following is an analysis of the existing as well as the expected pedestrian-vehicle conflicts resulting from pedestrian commuting to the academic zone.

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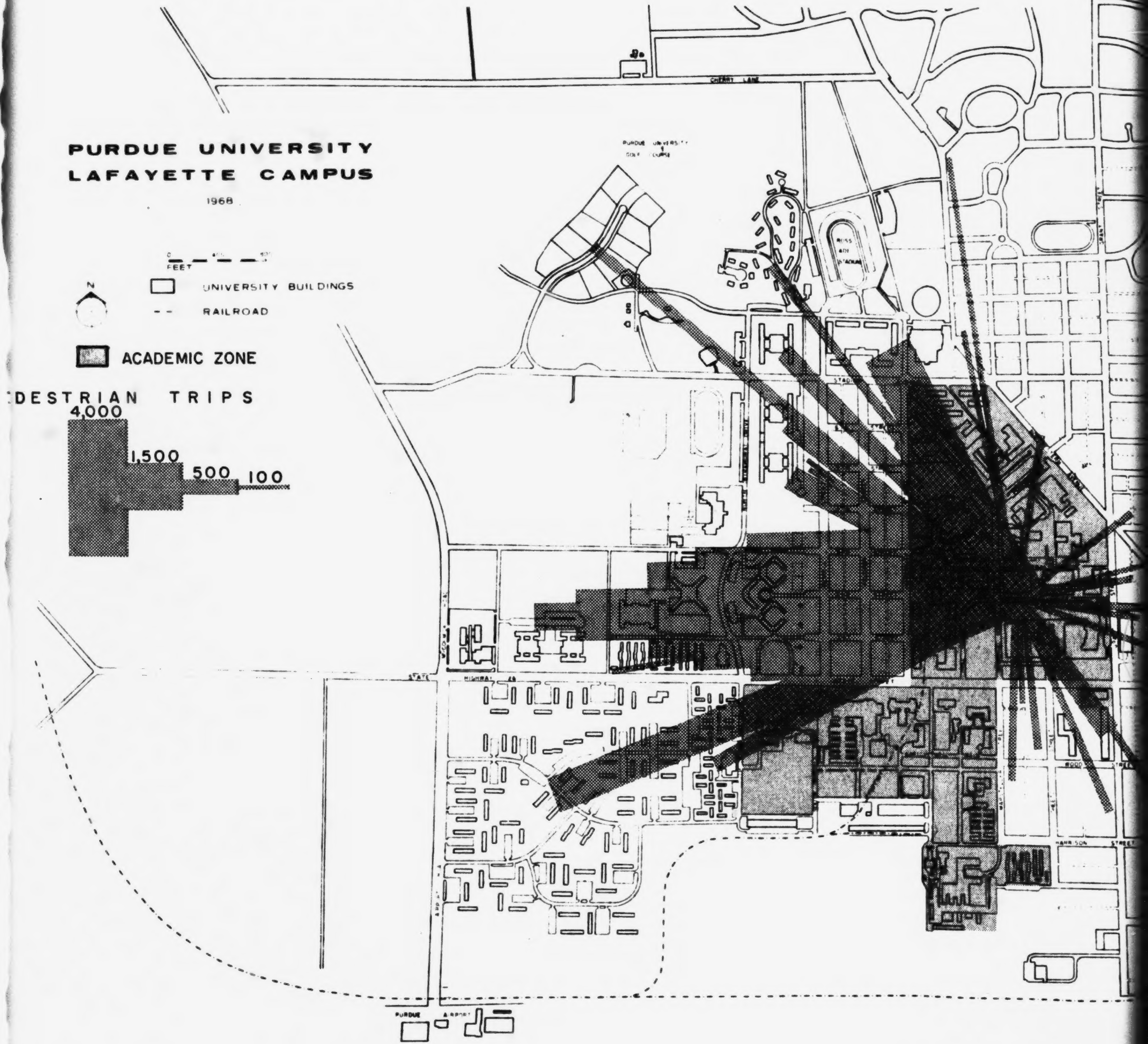
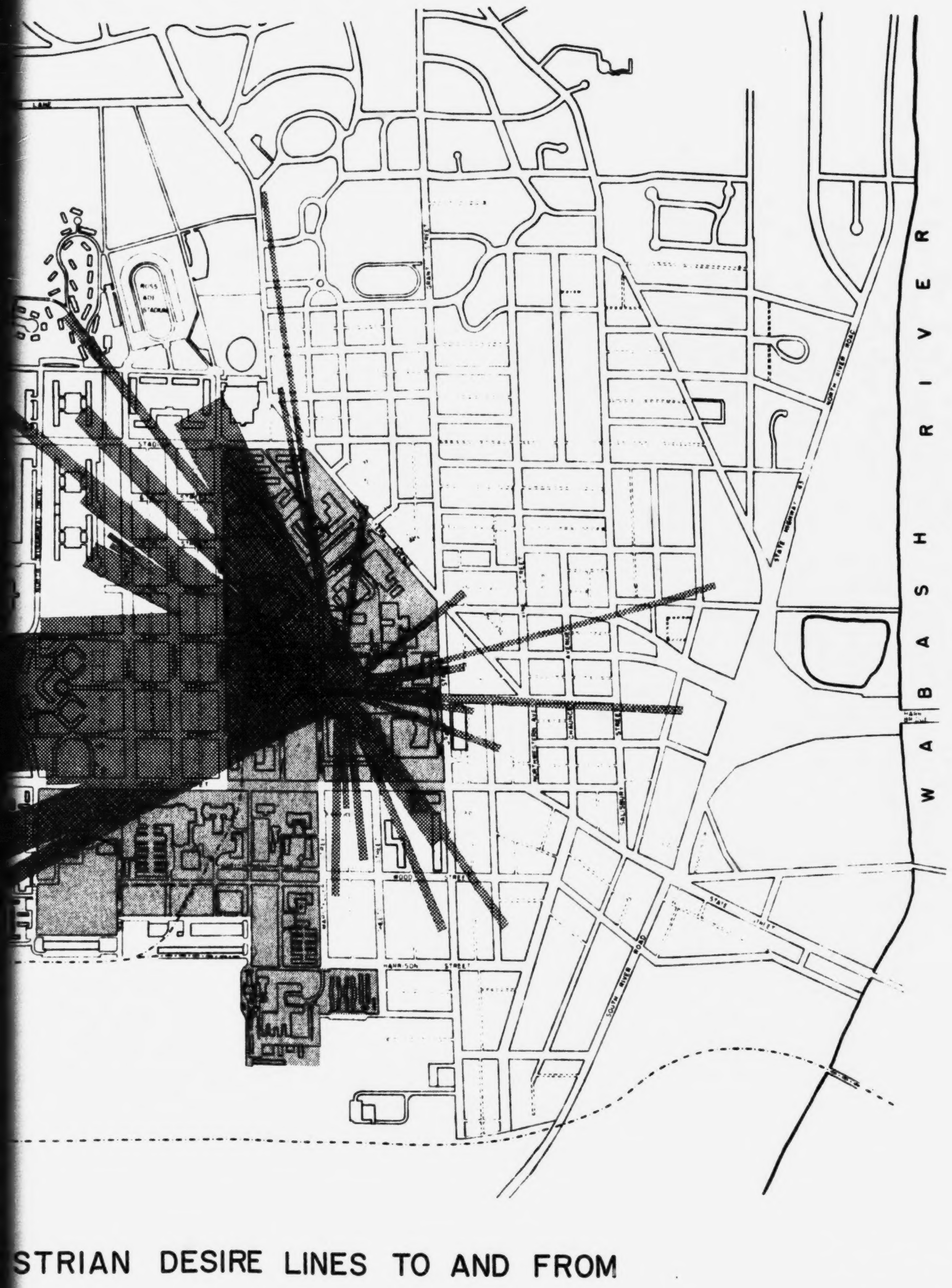
* To obtain accurate estimates of the expected student loads on a bus system at different hours would require the use of sophisticated data on the probable frequencies of student trips from the academic zone back and forth to their residences between classes.

The actual frequencies and paths of pedestrian trips made from origins outside of the academic zone to destinations within it are difficult to plot; more so to forecast. However, by plotting and examining schematic pedestrian desire lines based on estimates of pedestrian trips generated by different housing facilities and hypothetically attracted to the focal point in the academic zone, the locations of heavy pedestrian movements to and from the academic zone can be identified. Figure 15 shows a schematic configuration of the existing pedestrian desire lines to and from the academic zone. The heaviest pedestrian traffic approaches the academic zone from the west and the north; especially through First, Second, and Third Streets. In the future, the same pattern is expected to remain, probably with increasing pedestrian traffic approaching the academic zone from the south (due to the expected provision of additional graduate housing facilities south of State Street).

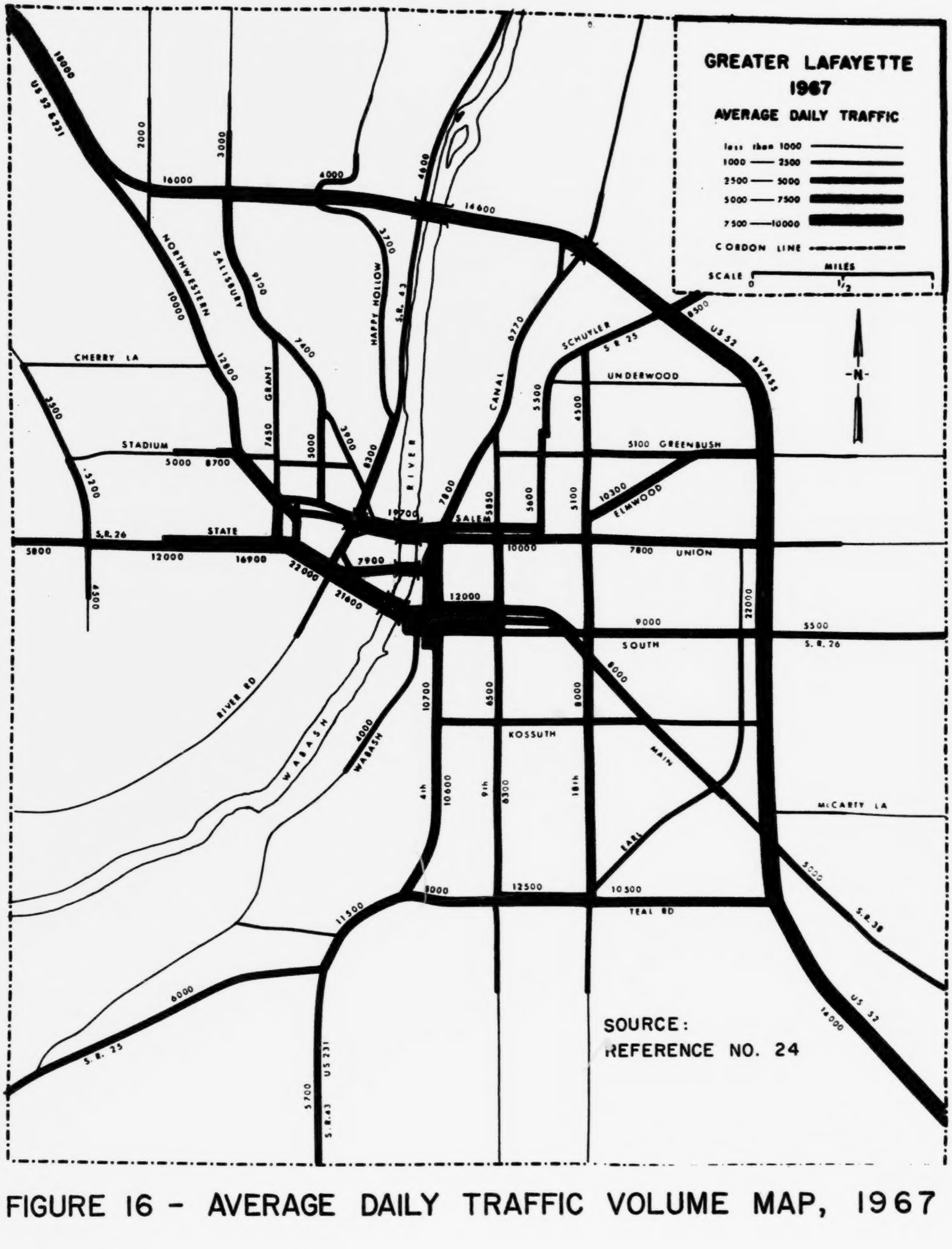
Existing volumes of vehicular traffic around the academic zone are shown in Figure 16 (24). Northwestern Avenue and State Street are the main approaches to the academic zone. Other surrounding streets carry much less vehicular traffic. These serve to distribute traffic to the parking facilities in and around the academic zone. Short of drastic changes in the street network around the academic zone, the same


PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
FEET
UNIVERSITY BUILDINGS
RAILROAD
N
ACADEMIC ZONE
DESTRIAN TRIPS
4,000
1,500
500
100
CHERRY LANE
PURDUE UNIVERSITY GOLF COURSE
ROSS ADE STADIUM
STATE HIGHWAY 26
GRANT STREET
WOOD STREET
HARRISON STREET
PURDUE AIRPORT

IGURE 15 – SCHEMATIC CONFIGURATION OF PEDESTRIAN DESIRE LINES TO A
THE ACADEMIC ZONE, FALL 1967


W A B A S H   R I V E R
ROSS ADE STADIUM
LANE
STADIUM
GRANT STREET
NORTHWESTERN AVE
CHAUNCEY
SALISBURY
STREET
WOOD STREET
HARRISON STREET
STATE STREET
SOUTH RIVER ROAD
NORTH RIVER ROAD
STATE HIGHWAY 43

STRIAN DESIRE LINES TO AND FROM


GREATER LAFAYETTE
1967
AVERAGE DAILY TRAFFIC
less than 1000
1000 — 2500
2500 — 5000
5000 — 7500
7500 — 10000
CORDON LINE
SCALE
MILES
0
1/2
1
N
US 52 & 231
18000
2000
3000
16000
4000
4600
14600
3700
NORTHWESTERN
SALISBURY
9100
HAPPY HOLLOW
S.R. 43
10000
12800
GRANT
7400
CANAL
6770
SCHUYLER
S R 25
8500
US 52
BYPASS
UNDERWOOD
CHERRY LA
2500
STADIUM
5000
8700
7450
5000
3900
8300
RIVER
5300
4500
5100 GREENBUSH
5200
7800
5850
5600
5100
10300
ELMWOOD
19700
SALEM
S.R. 26
STATE
5800
12000
16900
22000
7900
10000
7800
UNION
4500
21600
12000
9000
SOUTH
5500
S. R. 26
22000
RIVER RD
8000
10700
6500
8000
KOSSUTH
WABASH
4000
WABASH
MAIN
4th
10600
9th
8300
18th
McCARTY LA
EARL
5000
S.R. 38
8000
12500
10500
TEAL RD
11500
6000
S.R. 25
5700
US 231
S.R. 43
US 52
14000

SOURCE:
REFERENCE NO. 24

FIGURE 16 - AVERAGE DAILY TRAFFIC VOLUME MAP, 1967

traffic pattern is expected to remain unchanged in the future. Volumes of traffic, however, will obviously increase.

By examining the patterns of pedestrian traffic and vehicular traffic together, existing and expected pedestrian-vehicle conflicts can be located. Such conflicts presently occur and will tend to increase on Stadium Avenue, along University, Waldron, and Russell Streets, and most importantly on State Street. No significant conflicts seem to occur along Northwestern Avenue. Fortunately, peak vehicular traffic does not concur with peak pedestrian traffic. As such, pedestrian-vehicle conflicts around the academic zone may be subject to possible solutions.

Summary

This chapter discussed data collection, data analysis, and forecasting. The patterns of movement in the academic zone were analyzed, the efficiency of the present layout of facilities was evaluated, and the pedestrian-vehicle conflicts in the academic zone were located. Future expected conditions in the academic zone were discussed. Commuting to and from the academic zone was also examined. Data on the campus population characteristics influencing commuting were collected and analyzed. Expected future population characteristics were estimated and techniques for forecasting commuting demands were developed. Thus future parking demands and the peak student load on a possible bus system that might be used as an alternative mode of commuting to and from the academic zone were estimated. Finally, pedestrian-vehicle conflicts around the academic zone were examined.

The results arrived at in this chapter provide the factual bases on which a number of alternative circulation and commuting plans are developed in the next chapter.

CHAPTER III. ALTERNATIVE PLANS FOR CIRCULATION AND COMMUTING

The existing conditions relative to circulation in the academic zone and commuting to and from it were analyzed. Deficiencies were noted and future demands were estimated. A number of alternative plans were developed to overcome the existing deficiencies and meet the future demands. These were then evaluated in terms of their capabilities to fulfill objectives and in terms of their annual costs. The following are the objectives set for these alternatives and the criteria by which they were evaluated.

Objectives and Criteria

Objectives

In his general discussion of campus circulation systems, Dober proposed a number of objectives (5). On the basis of these, specific objectives were formulated to suit the purpose and scope of this study. The alternative plans for circulation and commuting were developed with the following objectives:

1. To create, whenever practicable, traffic-free pedestrian precincts in the academic zone.
2. To separate the channels of movement of incompatible modes of transportation.

3. To provide logical connections in traffic flow.
4. To meet, as adequately as feasible, the demand for parking.
5. To choose, within the limitations of land availability and uses, convenient locations for parking.
6. To provide for the appropriate servicing of buildings.
7. To create an aesthetically pleasing environment on the campus.

Criteria

Circulation and commuting plans were evaluated in terms of the following criteria: (1) continuity of the circulation system and clarity of destinations, (2) safety for both pedestrians and drivers, (3) convenience in driving and walking, (4) enjoyment of an aesthetically pleasing environment especially in walking, and (5) cost.

Alternative Circulation Plans (In the Academic Zone)

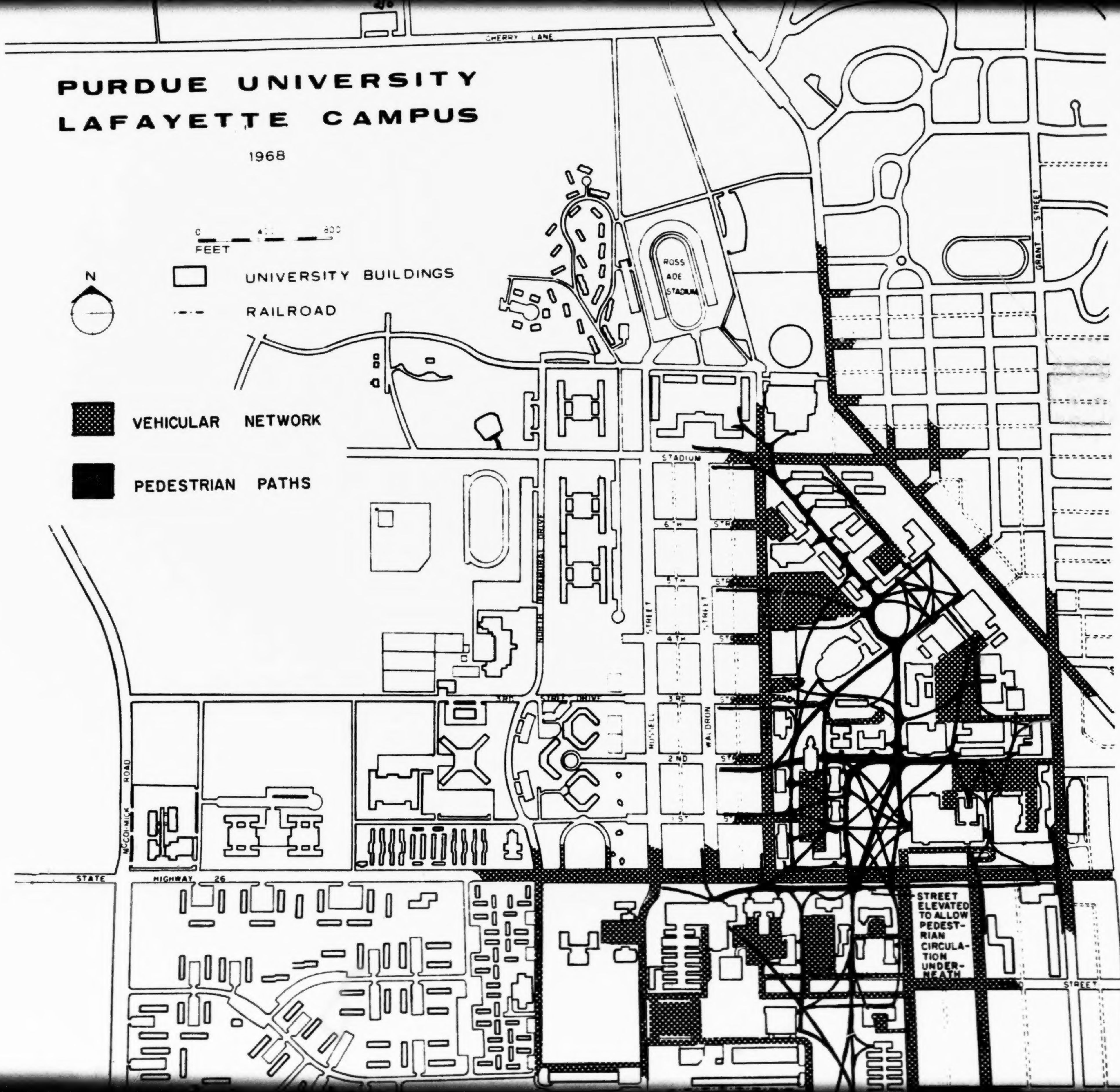
Analysis of pedestrian circulation in the academic zone indicated the presence of pedestrian-vehicle conflicts in a number of locations. Three alternative plans were developed to minimize these conflicts. In the first (alternative I/1) the conflicts are almost entirely eliminated. In the second and third (alternatives I/2 and I/3) the conflicts are partially eliminated with varying degrees. In all three alternatives, most parking facilities presently available on the periphery of the academic zone are kept in use. Buildings are serviced through these parking facilities. Whenever through vehicular traffic is eliminated by vacating or dead-ending internal streets, provision can be made for emergency vehicles to use pedestrian walkways for access. In all three alternatives, the railroad line is removed on the assumption that the existing power plant on the north campus will be relocated.

Alternative I/1

In this alternative, through traffic was completely eliminated from the academic zone. Pedestrian circulation is given prime importance while vehicular traffic is strictly kept to a minimum. Figure 17 shows alternative plan I/1. On the north campus, vehicular traffic was eliminated on Oval Drive, on Memorial Mall, south of the Chemistry building, on Central Drive, around the Hall of Music, on Purdue Mall, and on Stadium Mall. This was done to minimize the interference, in these locations, between vehicular traffic and the heavy concentrations of pedestrians. On the south campus, pedestrian-vehicle conflicts are as yet relatively less noticeable. However, a few changes were made in the existing vehicle circulation system to minimize increases in such conflicts in the future. Thus vehicular traffic was eliminated south of the Life Science Small Animal building, east of the Agricultural Engineering building, west of the Horticulture building, and west of the Agricultural Hall.

PURDUE UNIVERSITY
LAFAYETTE CAMPUS

1968


0
400
800
FEET
N
UNIVERSITY BUILDINGS
RAILROAD
VEHICULAR NETWORK
PEDESTRIAN PATHS
CHERRY LANE
GRANT STREET
ROSS ADE STADIUM
STADIUM
6TH ST
5TH ST
4TH ST
3RD ST
2ND ST
1ST ST
RUSSELL STREET
WALDRON STREET
NORTH INTRAMURAL DRIVE
3RD STREET DRIVE
McCORMICK ROAD
STATE HIGHWAY 26
STREET
STREET ELEVATED TO ALLOW PEDESTRIAN CIRCULATION UNDERNEATH

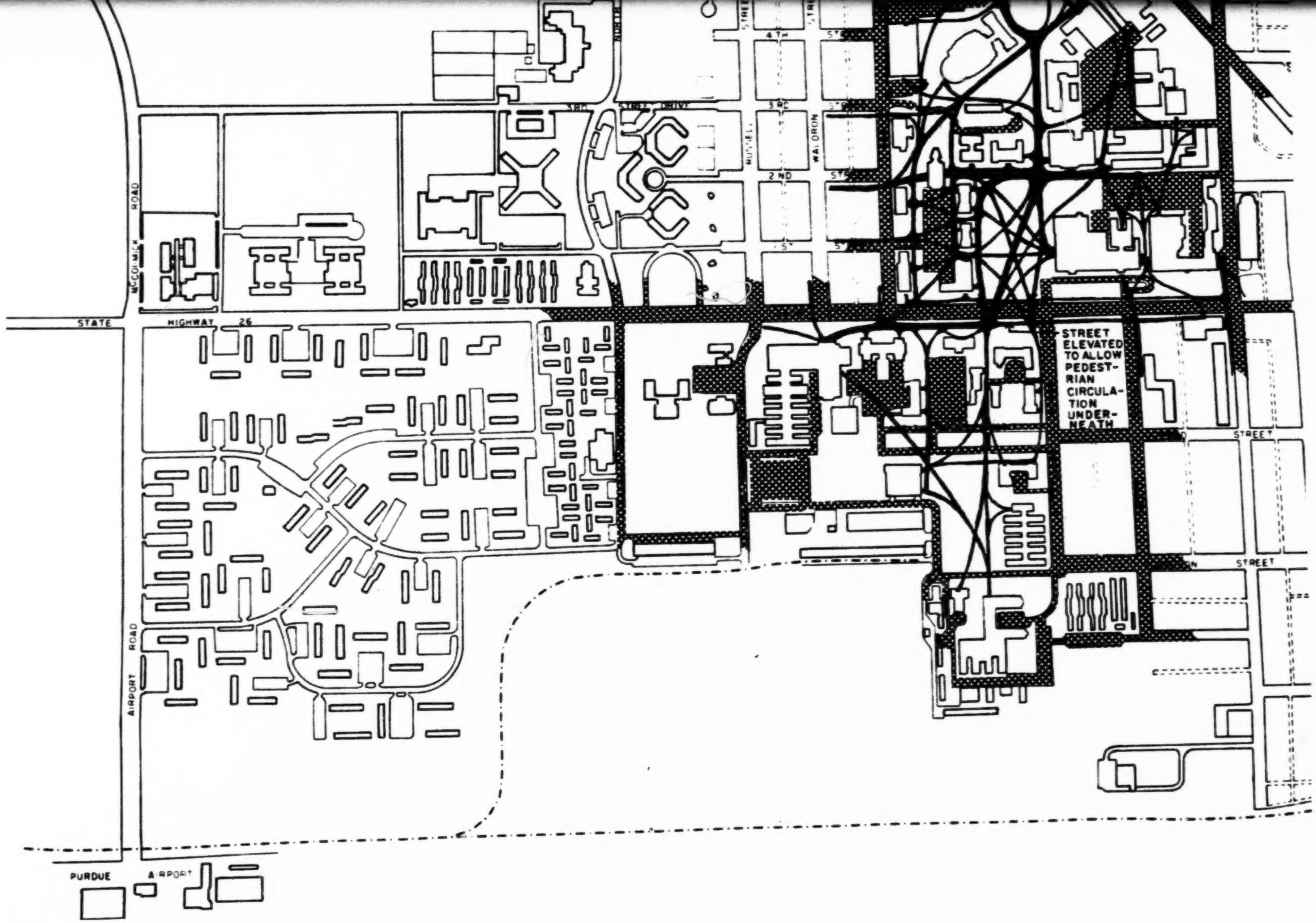

STREET ELEVATED TO ALLOW PEDESTRIAN CIRCULATION UNDERNEATH
STATE
HIGHWAY 26
McCORMICK ROAD
AIRPORT ROAD
PURDUE AIRPORT
RUSSELL
WALDRON
2ND
3RD
4TH
STREET
NORTH

FIGURE 17— ALTERNATIVE PLAN I/I -(CIRCULATION IN THE ACADEMIC ZONE)

It was recognized that the penetration of State Street into the campus creates one of the major pedestrian-vehicle conflicts in the academic zone, a conflict that is likely to increase considerably in the future. In this alternative, the solution proposed to overcome this conflict is based on the concept of complete integration of the south and north campuses. This is achieved by slightly raising the level of the stretch of State Street west of Memorial Mall and east of the Home Economics Administration building, and by slightly lowering the level of the open spaces north and south of this raised portion of State Street just enough to allow pedestrian movement underneath State Street (Figure 18). Continuity can thus be achieved in the flow of open spaces and in pedestrian circulation between the north and south campuses. The solution, however, requires considerable change in the design of the intersection of State Street with Marsteller Street.

Alternative I/2

Figure 19 shows alternative plan I/2. In this alternative, through traffic is also eliminated on the north campus. Peripheral parking facilities which do not conflict with major pedestrian paths are kept in use. The parking on Purdue Mall, northeast of the Music Hall, and north of the Memorial Center and Memorial Union are left unchanged. Major pedestrian-vehicle conflicts are minimized by converting Stadium Mall, Oval Drive, and Memorial Mall into pedestrian walkways. On the south

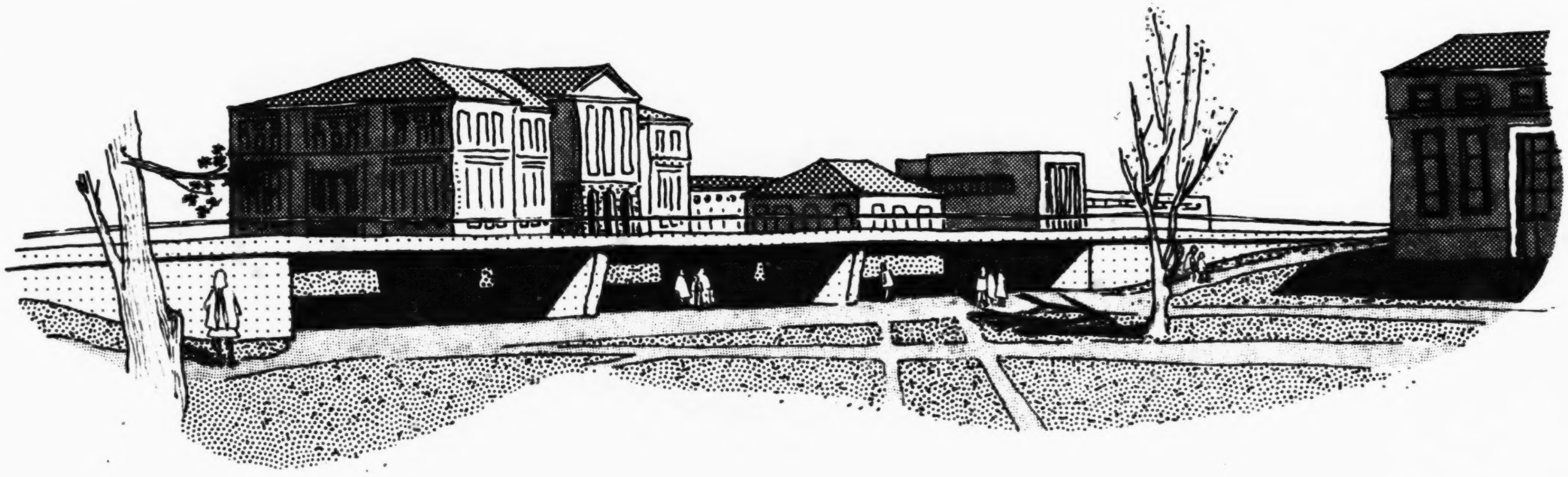
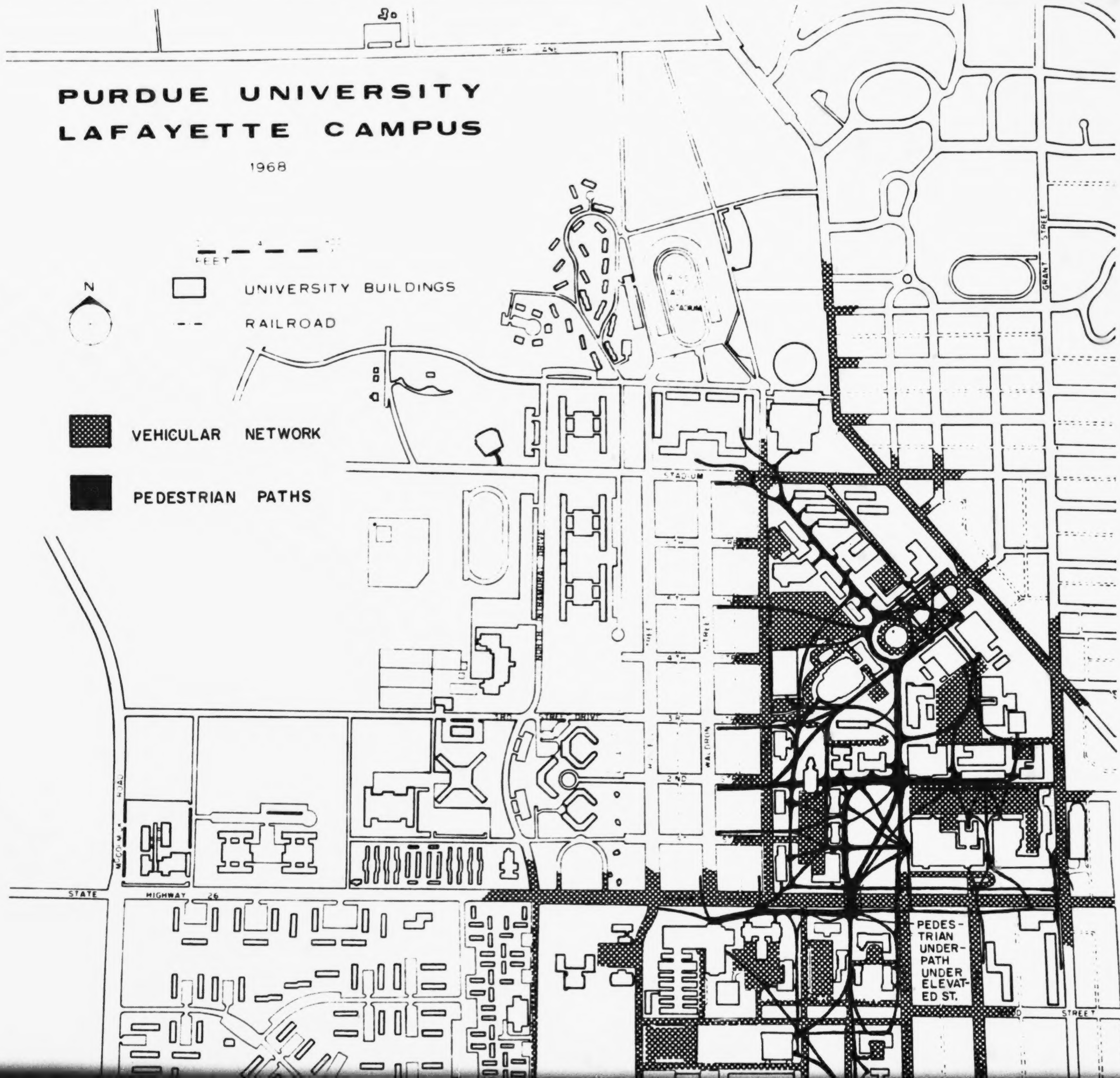


FIGURE 18 - PROPOSED INTEGRATION OF THE NORTH AND SOUTH CAMPUSES — A GENERAL VIEW

PURDUE UNIVERSITY
LAFAYETTE CAMPUS

1968


FEET
N
UNIVERSITY BUILDINGS
RAILROAD
VEHICULAR NETWORK
PEDESTRIAN PATHS
GRANT STREET
STADIUM
4TH
3RD
2ND
WALDRON
STREET
NORTH INTRAMURAL DRIVE
STATE HIGHWAY 26
MCCORMICK ROAD
PEDESTRIAN UNDERPATH UNDER ELEVATED ST.
STREET

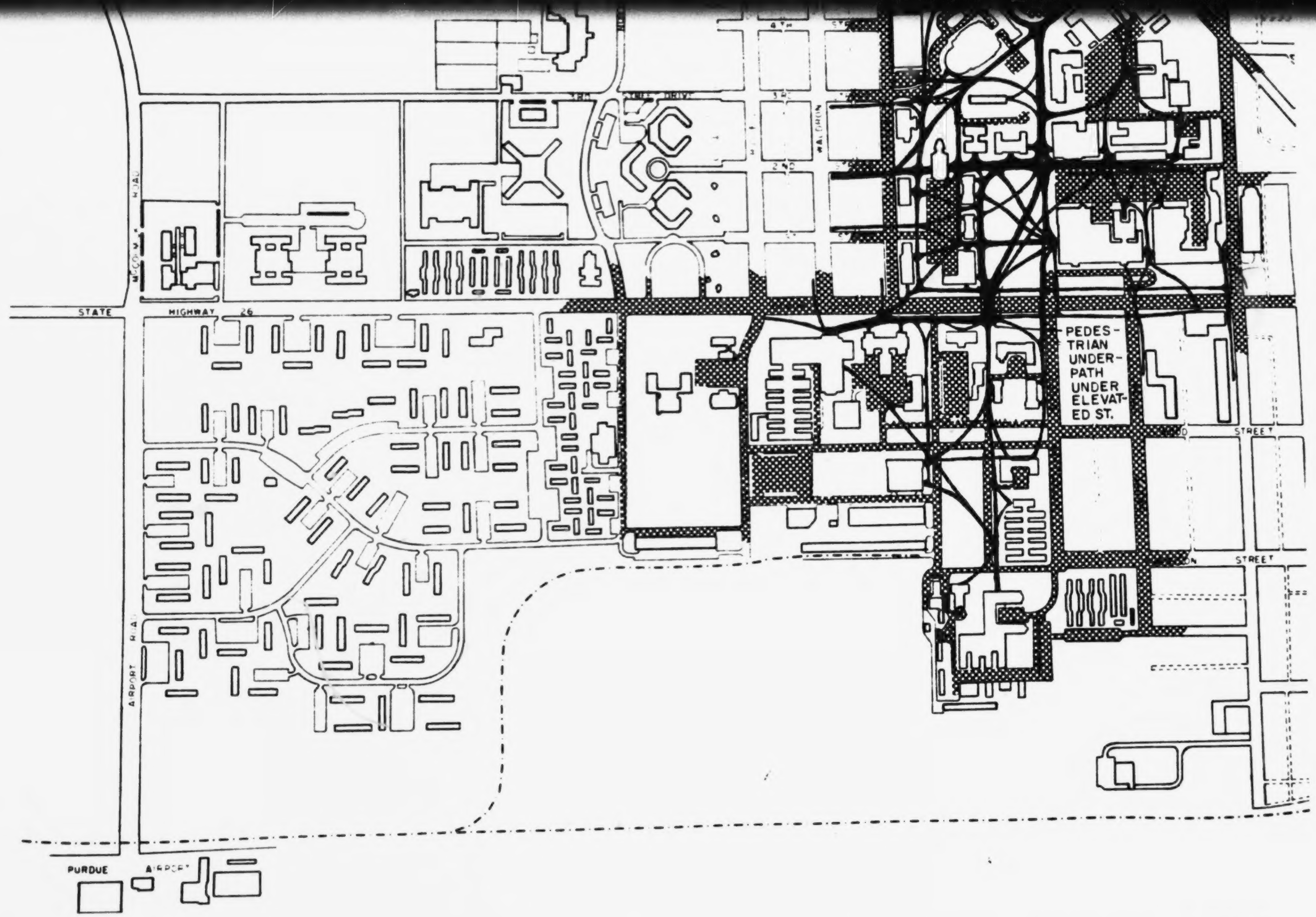

4TH ST
3RD ST
2ND ST
WALDRON
PEDESTRIAN UNDERPATH UNDER ELEVATED ST.
STREET
STREET
STATE HIGHWAY 26
McCORMICK ROAD
AIRPORT ROAD
PURDUE AIRPORT

FIGURE 19 - ALTERNATIVE PLAN I/2 - (CIRCULATION IN THE ACADEMIC ZONE)

campus, no changes are made in the circulation system. If the existing pattern of dead-end streets is maintained in the future, no major pedestrian-vehicle conflicts are likely to arise in the south campus.

To overcome the pedestrian-vehicle conflict on State Street, an open pedestrian underpass is proposed (Figure 20). In choosing the location of the underpass, the points at which the greatest concentrations of students cross State Street between classes were repeatedly observed. Accordingly, it was felt that the underpass would be most intensely used if located east of the Home Economics Administration building. Also, by slightly raising the level of State Street at this location and by slightly lowering the level of the proposed underpass (just enough to allow pedestrian movement), no major changes will be required in the adjacent intersections. The solution provides only partial integration of the north and south campuses but satisfactorily eliminates the major pedestrian-vehicle conflict on State Street.

Alternative I/3

Figure 21 shows alternative plan I/3. Unlike alternatives I/1 and I/2, this alternative seeks only to minimize (and not completely eliminate) through traffic on the north campus. Parts of Oval Drive, Central Drive, and Memorial Mall are closed to vehicular traffic. Stadium Mall is used for one-way traffic (going south) leading to the parking

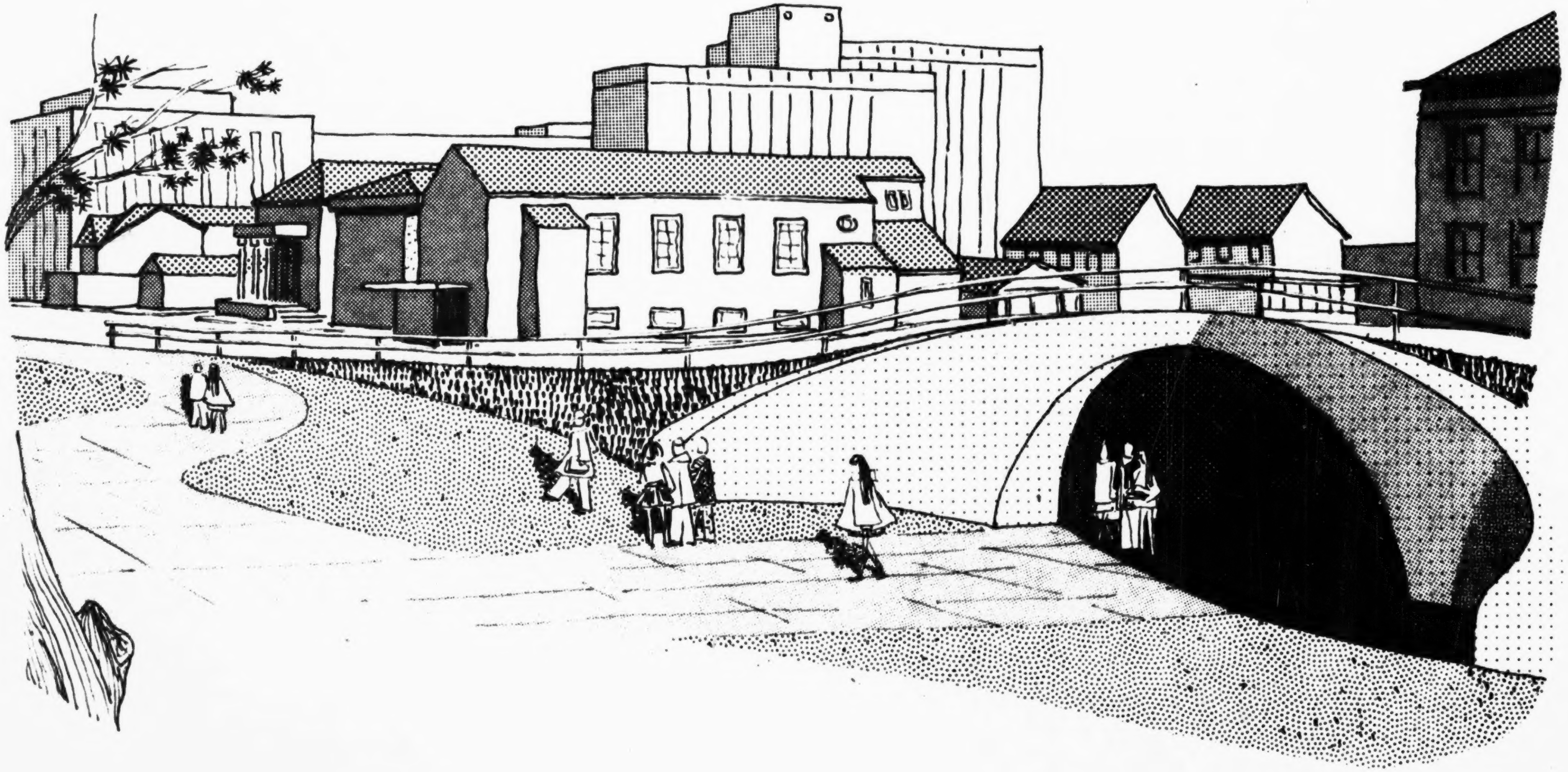
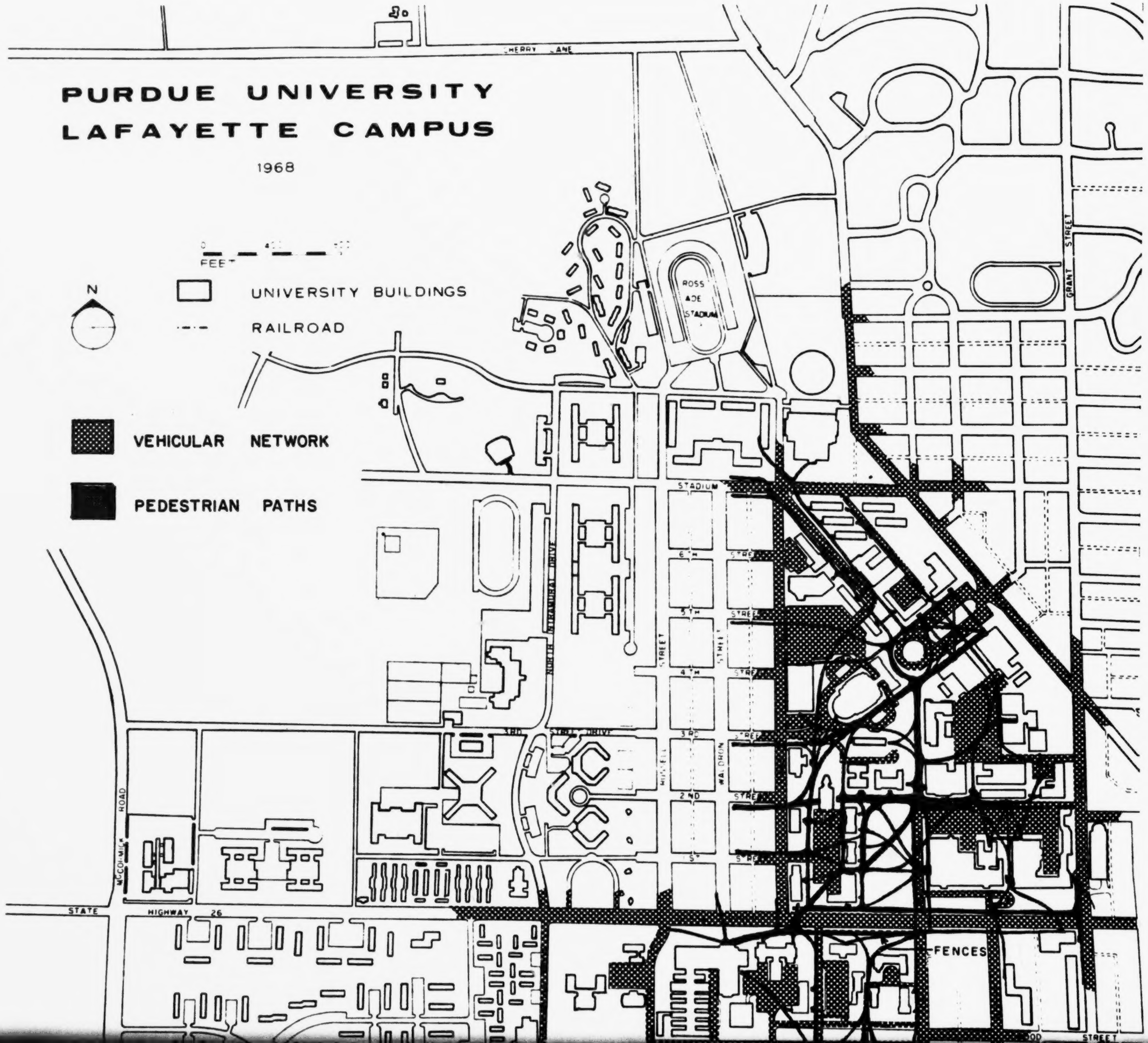


FIGURE 20 - PROPOSED PEDESTRIAN UNDERPASS - A GENERAL VIEW


PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
0
400
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FEET
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UNIVERSITY BUILDINGS
RAILROAD
VEHICULAR NETWORK
PEDESTRIAN PATHS
CHERRY LANE
ROSS ADE STADIUM
GRANT STREET
STADIUM
6TH STREET
5TH STREET
4TH STREET
3RD STREET
2ND STREET
1ST STREET
RUSSELL STREET
WALDRON STREET
NORTH INTRAMURAL DRIVE
3RD STREET DRIVE
McCORMICK ROAD
STATE HIGHWAY 26
FENCES
STREET

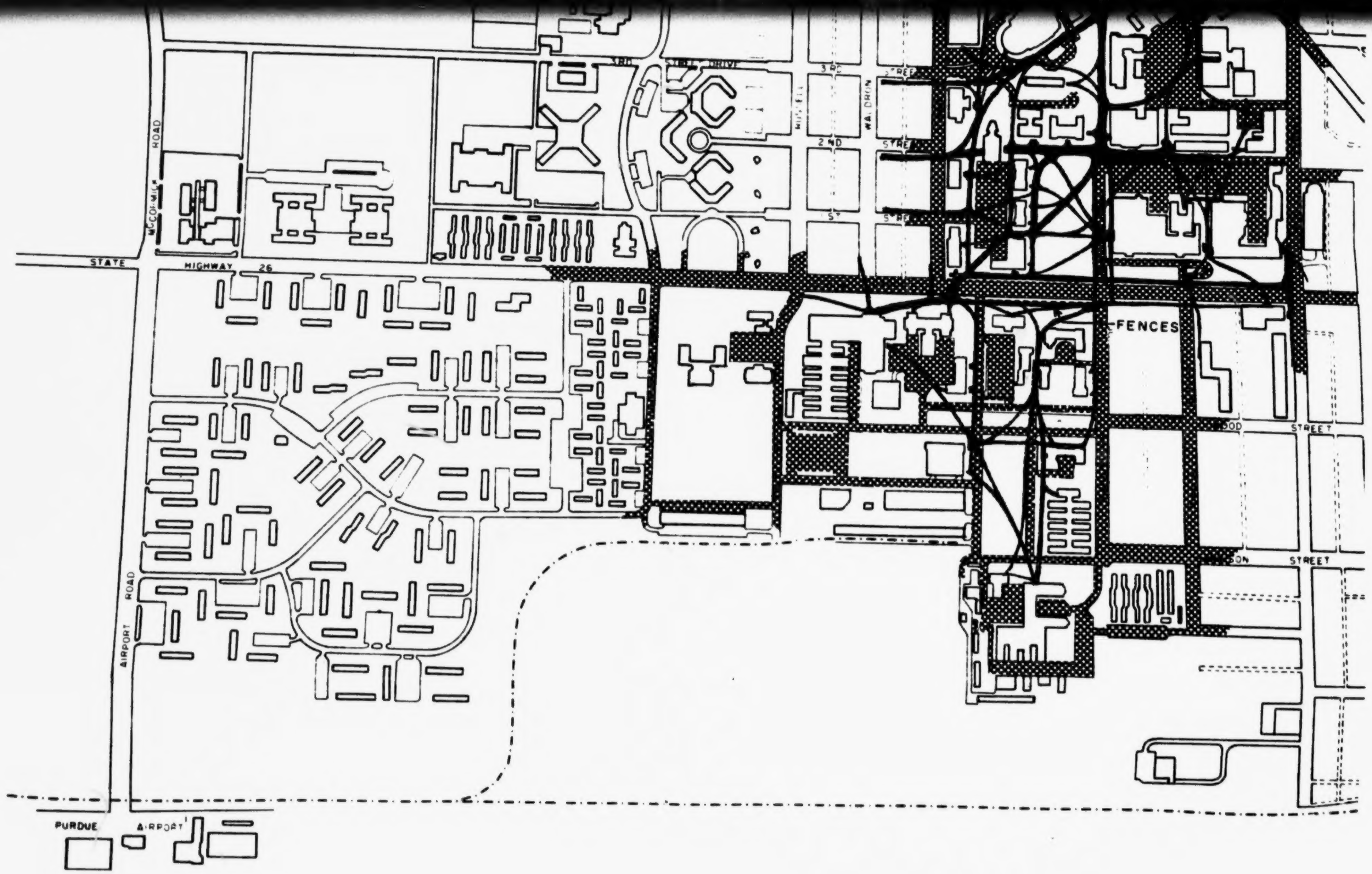
STATE
HIGHWAY 26
McCORMICK ROAD
AIRPORT ROAD
PURDUE AIRPORT
FENCES
3RD STREET
2ND STREET
STREET
3RD STREET DRIVE
RUSSELL
WALDRON
WOOD STREET
SON STREET

FIGURE 21 - ALTERNATIVE PLAN I/3 - (CIRCULATION IN THE ACADEMIC ZONE)

lot abutting University Street (Figure 21). As in alternative I/2, no changes are made on the south campus. The pedestrian-vehicle conflict on State Street is reduced by using a more complete system of decorative fences along the street to limit the points of crossing and by providing traffic controls at these points.

Evaluation of Alternatives

The following is a subjective evaluation of the three alternative circulation plans in terms of the criteria outlined earlier in this section. The evaluation is subjective in the sense that it does not attempt to quantify the attributes and characteristics of each alternative, but instead, discusses them qualitatively.

In both alternatives I/1 and I/2, continuity is fully achieved in both vehicular and pedestrian circulation. In alternative I/3, pedestrian circulation is interrupted, at a number of points, by vehicular traffic. In terms of safety, both alternatives I/1 and I/2 succeed in eliminating the major hazards caused by pedestrian-vehicle conflicts, but in alternative I/3 the conflict on State Street is not fully overcome.

In all three alternatives, driver convenience is reduced (to varying degrees) by eliminating access to parking facilities from internal streets (in the academic zone) and by limiting this access to single points on the surrounding streets. Not only will this mean longer trips in some cases (by automobile and on foot), but it might also create some mild traffic congestion on the surrounding streets during peak hours. Access for service and emergency vehicles can be adequately provided in all three alternatives.

Aesthetically, the potential exists in all three alternatives for creating pleasing visual relationships in the academic zone. In alternatives I/1 and I/2, the grade separation of pedestrians and vehicular traffic on State Street creates wide possibilities of landscaping and open space organization.

For this evaluation, cost was found to result primarily from two measures: (1) the number of parking spaces in the academic zone that would be lost due to the proposed changes, and (2) the extensiveness of the proposed changes. Alternative I/1 has the greatest reduction in the number of parking spaces (about 766 spaces). Of the three alternatives, it also proposes the most extensive changes in the existing conditions. As such, it will undoubtedly prove to be the most expensive to implement. Conversely, alternative I/3 will result in reducing the number of the existing parking spaces in the academic zone by only about 142 spaces and will require the least extensive changes. Alternative I/2 lies between the two extremes; it involves the reduction of about 302 parking spaces and requires moderate changes in the existing conditions.

On the basis of this evaluation, it seems justified to conclude that, of the three proposed alternatives, alternativ I/2 would be most acceptable. It will minimize the major pedestrian-vehicle conflicts in the academic zone; it will reasonably link the north and south campuses; and it would require only moderate costs to effect necessary changes in the existing conditions. Alternative I/2 is consequently used as the basis for developing alternative commuting plans.

Alternative Commuting Plans (To and From the Academic Zone)

Commuting to and from the academic zone and circulation in the academic zone, although examined separately, are interrelated. Both are phases of an integral campus transportation system. The alternative commuting plans proposed in this section, therefore, are developed in connection with the selected circulation plan (alternative I/2). However, few changes are expected to arise (especially in future parking demands) if some other circulation plan (in the academic zone) is selected.

Three alternative commuting plans are proposed. In the first (alternative II/1), it is assumed that all expected auto trips to the academic zone will terminate in or around it. Therefore, all future parking demand (for students, staff, and visitors) is provided in and around the academic zone. The second (alternative II/2) uses a combination of parking facilities around the academic zone and a bus system to move students from university housing facilities to the academic zone. The third and last (alternative II/3) is based on the concept of providing parking facilities in relatively remote locations and moving commuters from these parking lots to the academic zone by mass transportation. Two types of mass transportation systems are compared. In sub-alternative II/3-A, a street bus system is proposed and in sub-alternative II/3-B, the possibility of using a skybus system operating on an elevated roadway is discussed.

In all three alternatives, no additional parking is provided on the north campus. Of the existing on-street free parking around the academic zone, 1000 spaces are assumed to be available for commuter parking in the future. In addition to these and the existing parking spaces in the academic zone, it was estimated that, to meet the future commuting demands of students, staff, and visitors, about 4330 additional spaces will either have to be provided or some other mode of commuting to the academic zone will have to be developed.* In developing the alternative commuting plans, due consideration was given to pedestrian commuting. Locations of future parking facilities were chosen so as to minimize pedestrian-vehicle conflicts and to allow for appropriate traffic controls at major pedestrian crossing points.

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* For the details of this estimate, see Appendix B - Section 2.

Alternative II/1

In this alternative, future commuting demands are met by providing parking facilities around the academic zone. Figure 22 shows alternative plan II/1. A number of possible kinds and locations of parking facilities were examined. A comparison was made between the annual costs of different kinds of parking facilities such as underground garages, multi-story above ground garages, and surface parking. The costs of providing parking facilities on university owned land and on non-university owned land were also compared. Appendix B - section 1 shows a detailed comparison of the annual costs of four kinds of parking facilities. Underground parking in the academic zone was discarded because of its relatively high costs. Surface parking on close-by locations around the academic zone in most cases was rejected because of the limited availability of usable land in general and university owned land in specific. The provision of parking in multi-story above ground garages around the academic zone was found to be the least expensive and the most appropriate from a land use and pedestrian circulation point of view. On the fringes of the south campus, however, surface parking is most economical because of university owned land.

In deciding upon the locations of future parking facilities (Figure 22), a number of factors were taken into consideration:

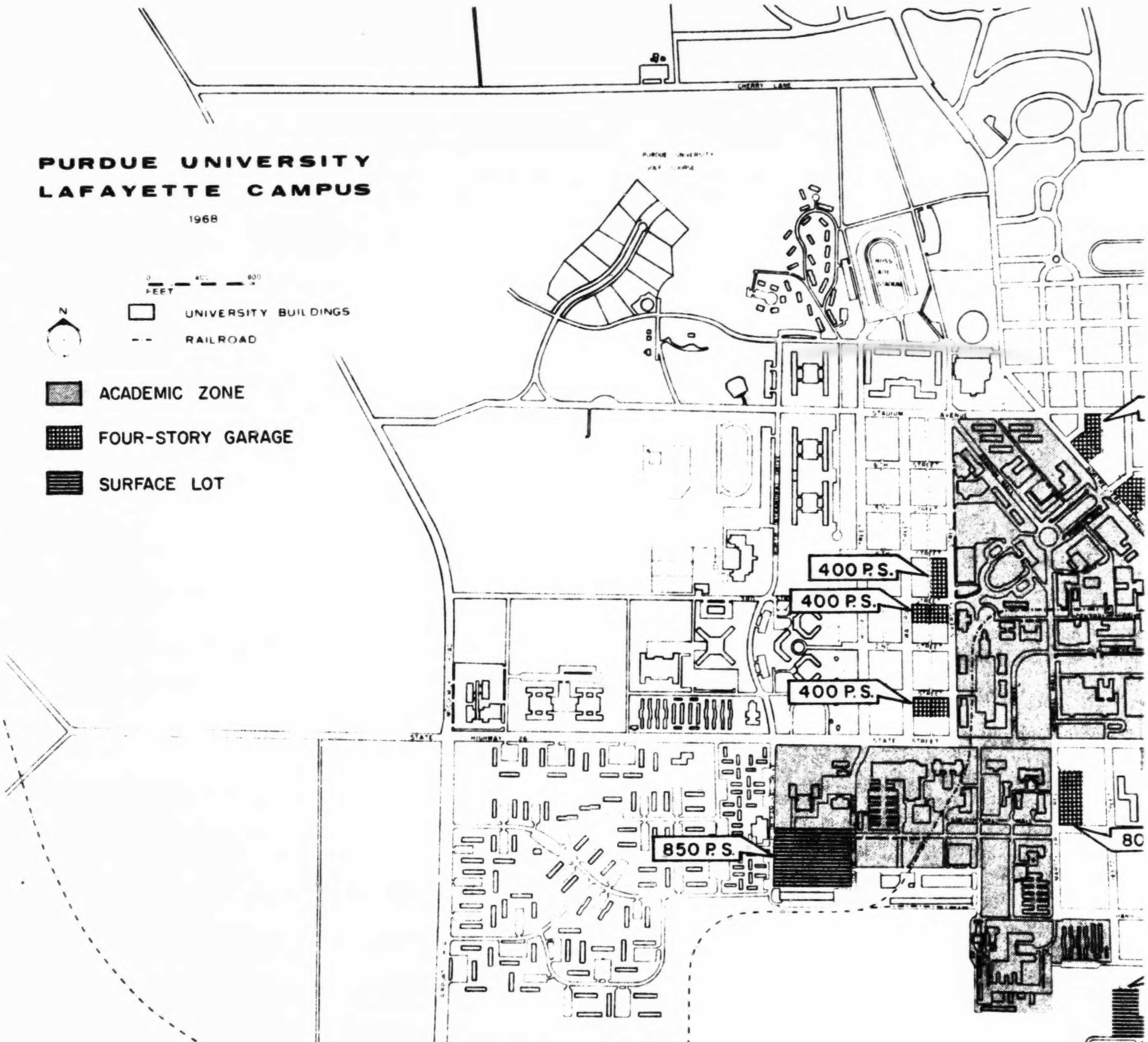
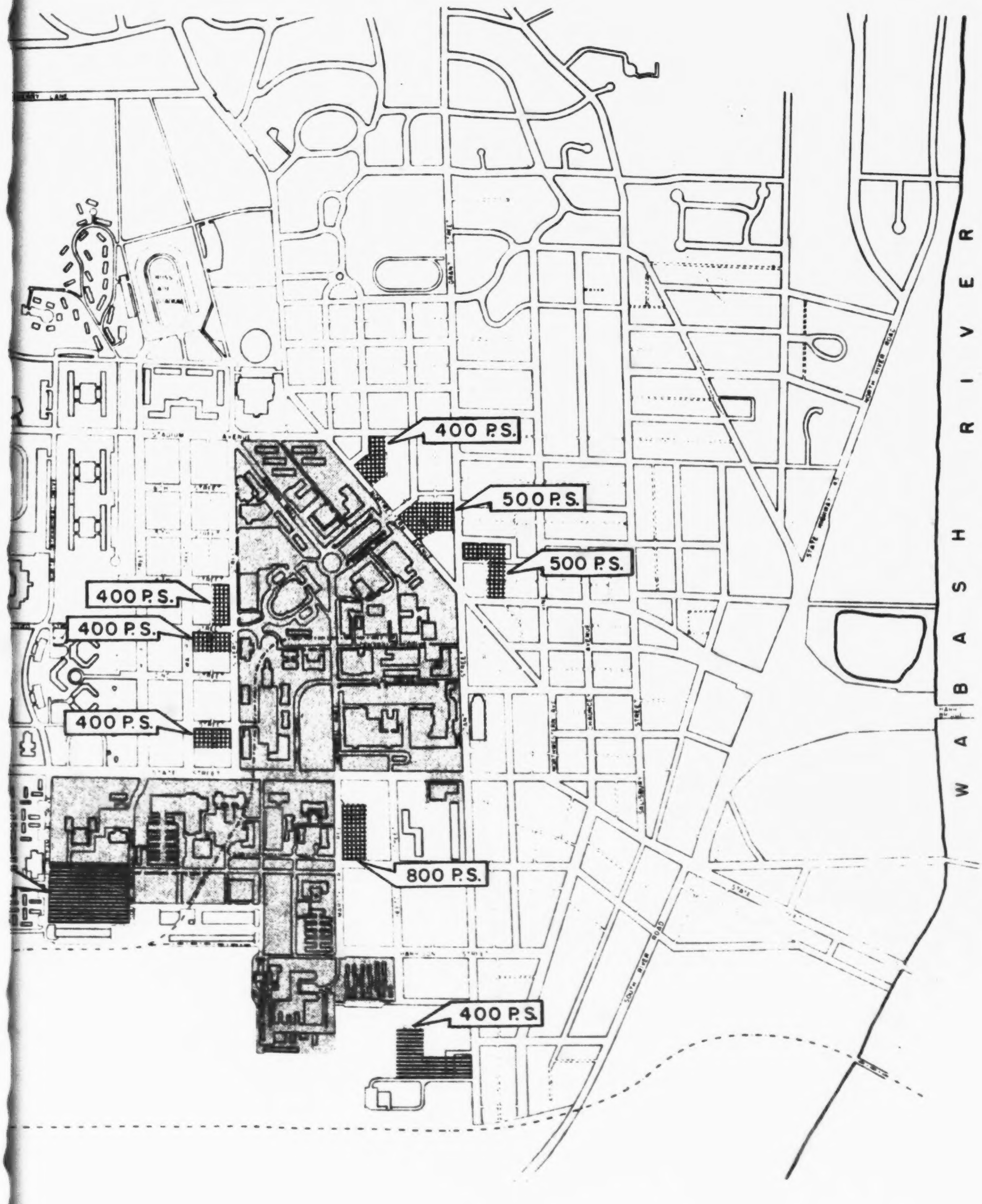

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
FEET
N
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
FOUR-STORY GARAGE
SURFACE LOT
CHERRY LANE
STADIUM AVENUE
STATE HIGHWAY 26
STATE STREET
400 P.S.
400 P.S.
400 P.S.
850 P.S.
80

FIGURE 22 — ALTERNATIVE PLAN II/I - (COMMUTING TO AND FROM THE


400 P.S.
500 P.S.
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400 P.S.
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800 P.S.
400 P.S.
W A B A S H   R I V E R

MUTING TO AND FROM THE ACADEMIC ZONE)

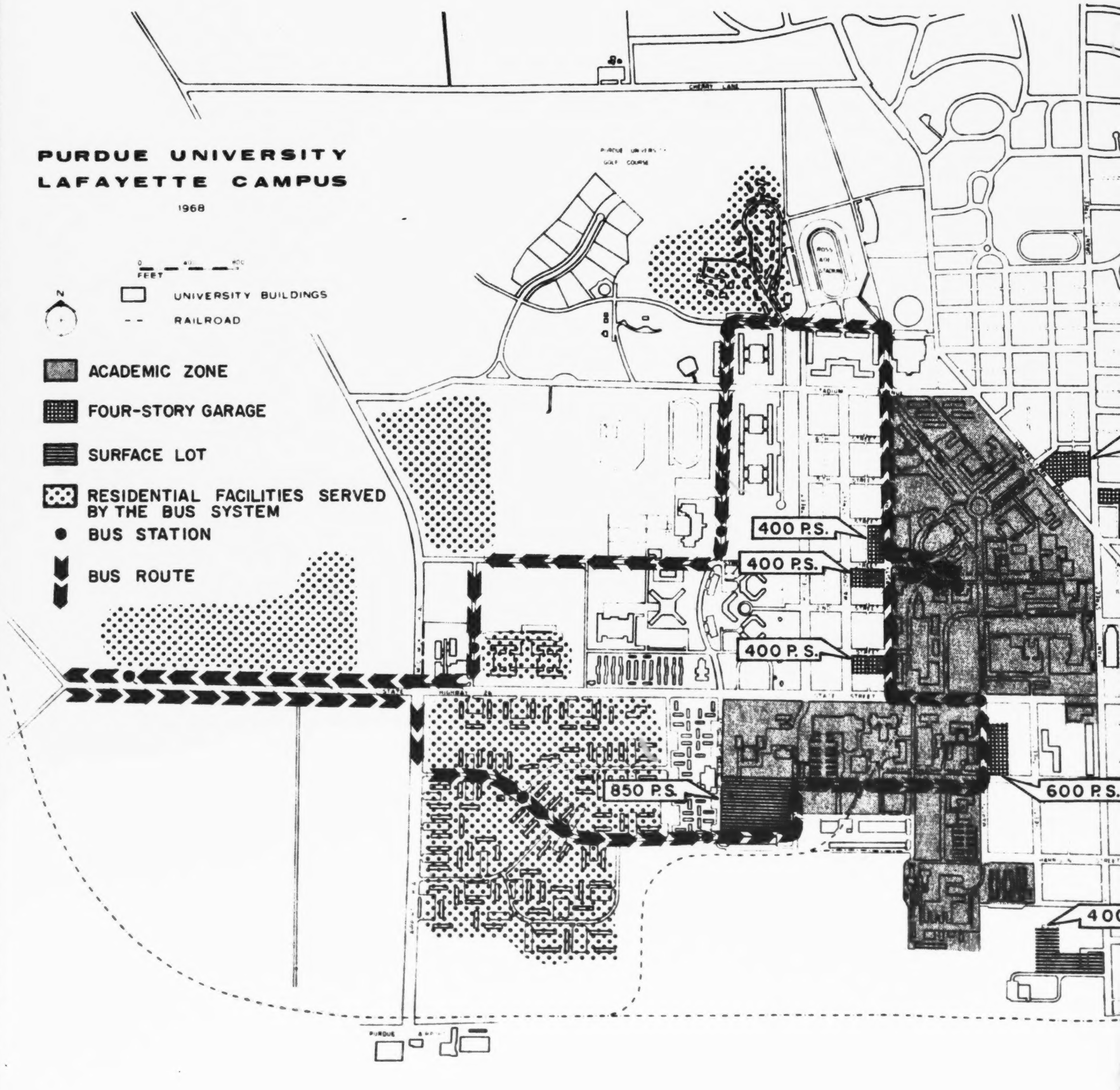
1. Parking facilities should be located, whenever possible, near the major traffic approaches to the academic zone. This enhances driver convenience and minimizes unnecessary vehicular movement around the academic zone. Thus, locations on Northwestern Avenue, University Street, Grant Street, Fowler Street and Wood Street were chosen for multi-story garages.
2. Location of parking facilities should minimize conflict at points of major pedestrian crossings. The entrances and exits of such facilities should be carefully designed to minimize pedestrian-vehicle conflicts. Thus, parking facilities on University Street were not located adjacent to Second Street because of the expected heavy pedestrian use of this street. However, if a pedestrian ramp along Second Street with a separated crossing of University Street were to be integrally constructed as a part of a garage on the south side of Second Street between Waldron and University Streets, separation of pedestrians and vehicles would be better accomplished.
3. In choosing parking locations, proximity to intensely used facilities in the academic zone secures pedestrian convenience. Multi-story garages were, therefore, located as close as possible to the main instructional facilities in the academic zone.

Along these lines, alterntative II/1 provides about 1250 parking spaces in surface lots on the south campus and about 3400 parking spaces in multi-story garages around the academic zone (Figure 22). The annual cost involved in implementing this alternative is estimated in Appendix B - section 2.

Alternative II/2

This alternative is developed on the basis of providing a combination of parking facilities around the academic zone and a bus system. Two possible systems were considered: (1) a bus system connecting the academic zone to the principal apartment complexes in West Lafayette and to the university housing facilities, and (2) a bus system connecting the academic zone to the university housing facilities only. The first was discarded because of the excessively long trip involved and the long time required to make such a trip by bus. The second was used as a basis for developing this alternative.

Since this proposed bus system is operated only between the academic zone and university housing facilities, it likely will substitute for only a fraction of the need for auto trips. The system is thus combined with parking facilities around the academic zone to meet the future commuting demand. Figure 23 shows alternative plan II/2. The figure gives the proposed bus route as well as the types and locations of the parking facilities around the academic zone.


PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
0
400
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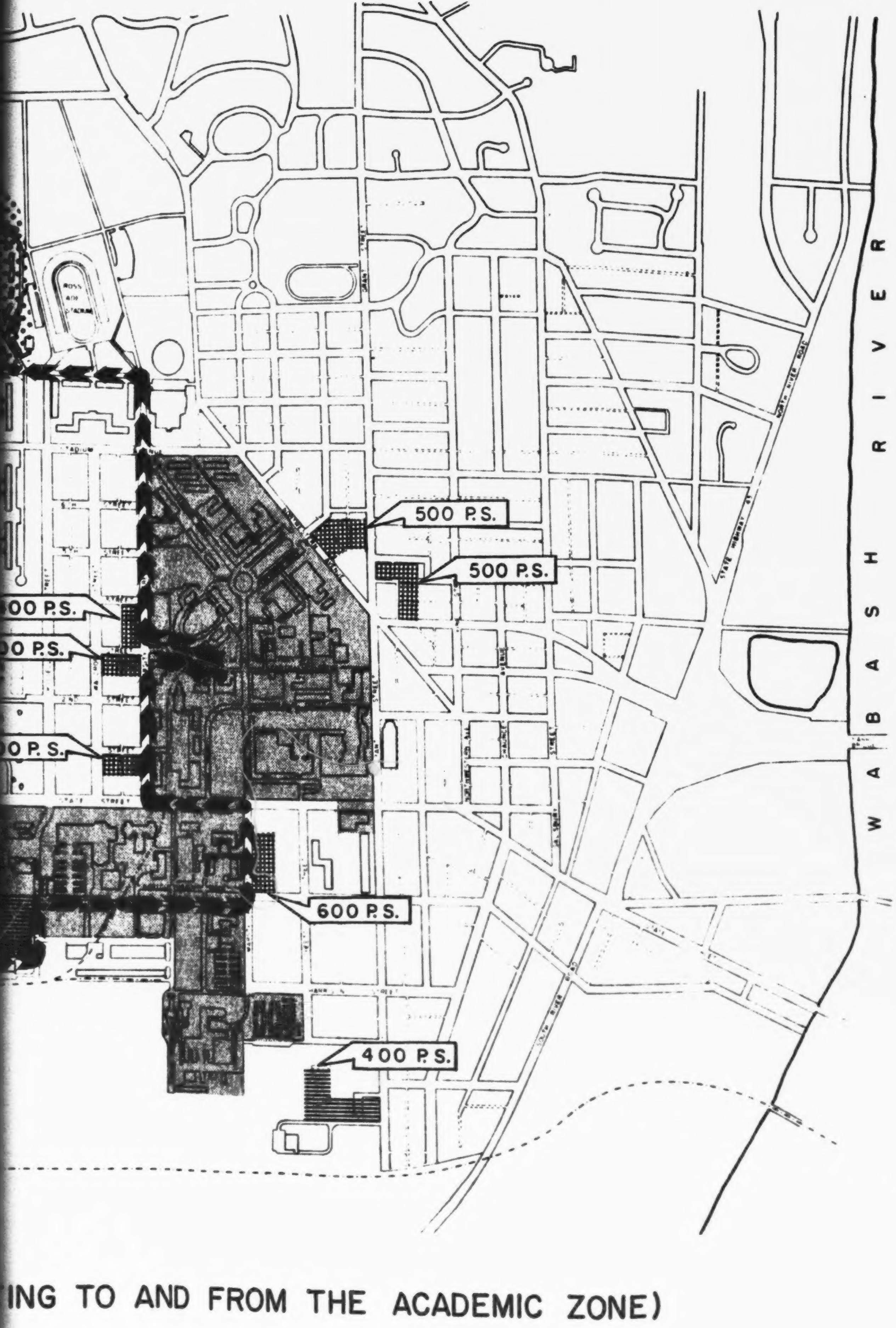
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
FOUR-STORY GARAGE
SURFACE LOT
RESIDENTIAL FACILITIES SERVED BY THE BUS SYSTEM
BUS STATION
BUS ROUTE
CHERRY LANE
PURDUE UNIVERSITY GOLF COURSE
ROSS ADE STADIUM
STADIUM
STATE HIGHWAY 26
400 P.S.
400 P.S.
400 P.S.
850 P.S.
600 P.S.
400
PURDUE AIRPORT

FIGURE 23 – ALTERNATIVE PLAN II/2 – (COMMUTING TO AND FROM THE


ROSS ADE STADIUM
500 P.S.
500 P.S.
00 P.S.
00 P.S.
00 P.S.
600 P.S.
400 P.S.
STATE STREET
NORTH RIVER ROAD
WABASH RIVER

ING TO AND FROM THE ACADEMIC ZONE)

According to this bus route, the round trip would be about five miles long. The types and locations of the parking facilities provided around the academic zone are not much different from those proposed in alternative II/1. Their capacities, however, are reduced by about 600 spaces assuming that all peak-hour non-pedestrian commuters living in university housing facilities will use the proposed bus system to the academic zone instead of their private automobiles. The peak load on the bus system is estimated as equal to the number of student auto trips made by students living in university housing facilities to the academic zone around 8:30 a.m.* This peak load was found to be about 430 passengers and is expected to occur shortly before 8:30 a.m.

The requirements of the bus system were estimated on the basis of the following operational criteria:

1. The system should be able to move a peak load of about 430 passengers from university housing facilities to the academic zone in not more than twenty minutes.
2. A minimum headway of about three minutes and a maximum of about ten minutes were allowed.
3. The system is used from 7:00 a.m. till 6:00 p.m. on average weekdays and from 7:00 a.m. to 12:00 noon on Saturdays and only on days when classes are in session.

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* Estimation of the peak load on the bus system is discussed in detail in Chapter II.

4. The average speed of the bus on the round trip is about eight miles per hour including stops and time allowed between trips (determined by field tests over the proposed route with reasonable loading, unloading, and terminal stops).
5. The peak occupancy of the bus is about seventy passengers (25).

On the basis of these criteria and the estimated peak load, nine bus units would be needed. The detailed estimates of the requirements of the system and the annual cost of implementing alternative II/2 appear in Appendix B - section 3.

Alternative II/3

Unlike alternatives II/1 and II/2, in this alternative, no additional parking facilities are provided around the academic zone. Instead, parking is provided in relatively remote locations and bus systems are operated to move parkers from these remote parking facilities to the academic zone. Two types of bus systems were compared: (1) a regular street bus system, and (2) a new transportation device known as the skybus. Sub-alternative II/3-A proposes two remote parking facilities both connected to the academic zone by means of street bus systems. Sub-alternative II/3-B proposes the same parking facilities. Of these, one is connected to the academic zone by a street bus system while the other is connected by a skybus system. The two sub-alternatives (A and B) are developed primarily to compare the two types of bus systems.

In choosing the locations of remote parking facilities, several sites were considered: (1) the Ross Ade Stadium parking lot, (2) the gravel pit south of the academic zone, (3) the intramural field west of the academic zone, and (4) the open space at the corner of Airport Road and State Street west of the married students courts. The gravel pit was discarded quickly because of its poor access and since its use would require a large amount of fill. Also to preserve the continuity of open spaces north of the single student housing facilities on State Street, the intramural field was not chosen for use as a parking facility. Thus the Ross Ade Stadium and the Airport Road locations were chosen. These locations have two advantages: (1) they abut the two main traffic approaches to the academic zone; namely, Northwestern Avenue and State Street, and (2) their proximity to university housing facilities (especially married students' housing) will probably encourage residents of these facilities to commute by the connecting buses and thus reduce the student demand on parking around the academic zone (and in the remote parking facilities). In deciding on which kind of parking facilities to provide at these locations the assumption was made that since these sites are presently owned by the university, their use would require no land cost. Under this assumption, surface parking was found to be the least expensive and was thus used.

It was earlier estimated that, in the future, 4330 parking spaces will have to be provided to meet the demand for commuting to the academic zone. If all non-pedestrian commuters living in university housing facilities use the bus systems connecting the remote parking facilities to the academic zone, this estimate is expected to be reduced to 3730 parking spaces. These were distributed between the two remote parking facilities in such a way that both of the bus systems connecting these facilities to the academic zone would carry an equal peak student load. Thus 2100 parking spaces were provided in the Ross Ade Stadium parking facility and 1630 in the Airport Road facility.

The expected peak student load on both bus systems was earlier estimated to be about 2150 students* (around 8:30 a.m.). In this alternative, each system carries a peak student load of about 1075 students. Having chosen the locations of the remote parking facilities, determined the capacity of each, and established the peak load on the bus systems connecting them to the academic zone, the two types of bus systems were compared.

Sub-Alternative II/3-A. In this sub-alternative, two street bus systems were provided between the remote parking facilities and the academic zone. Figure 24 shows the

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* Estimation of the peak load on the bus systems is discussed in detail in Chapter II.

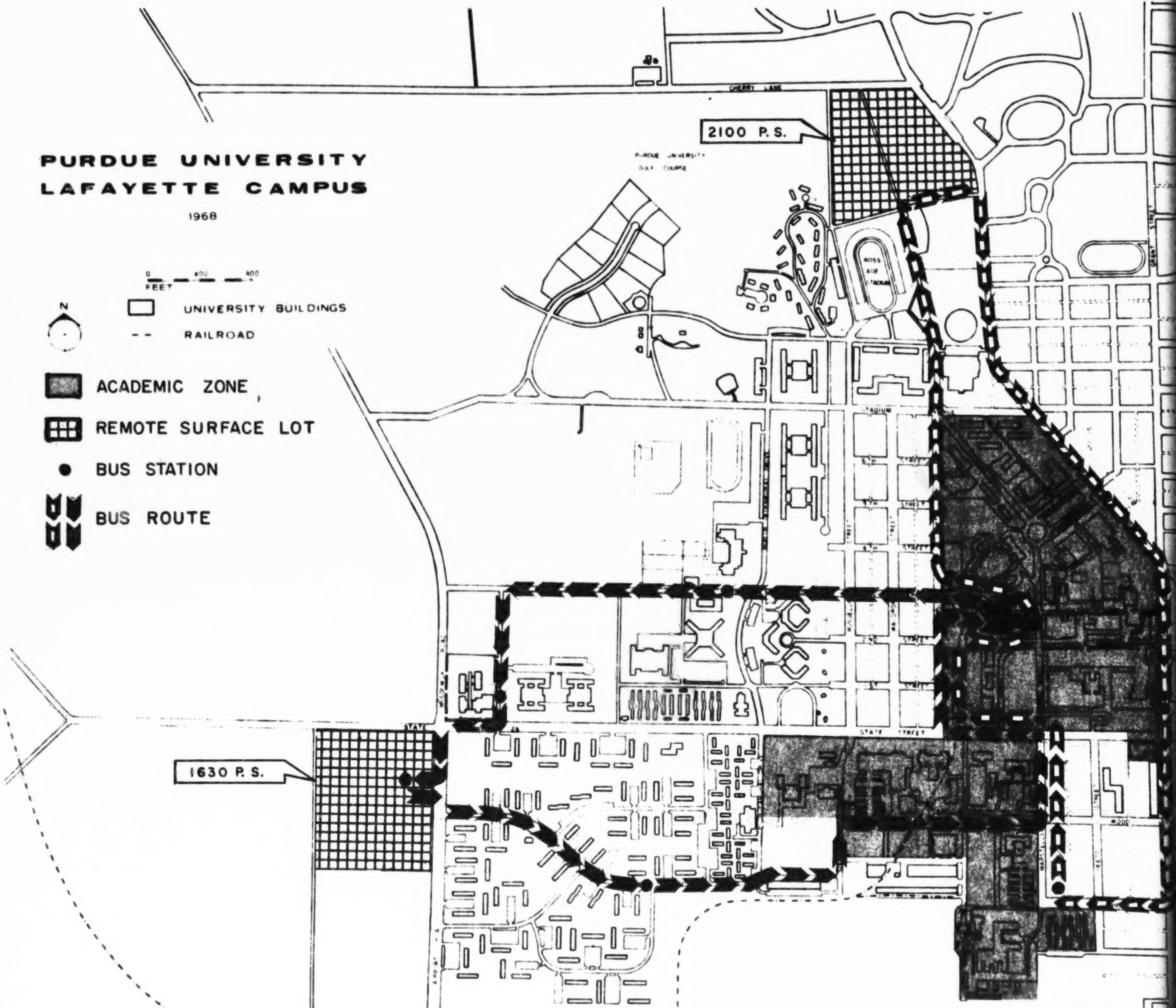
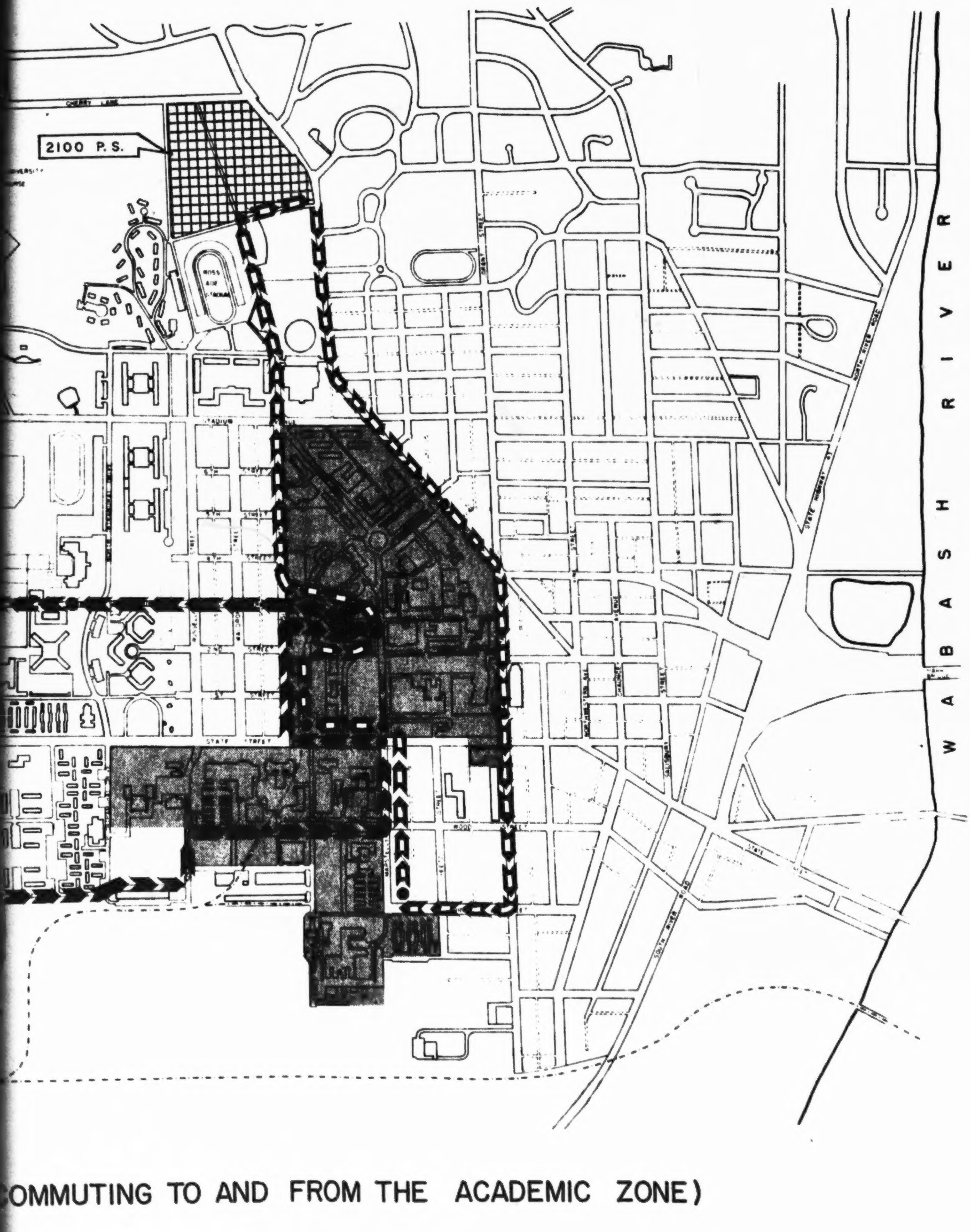

PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
0 400 800
FEET
N
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
REMOTE SURFACE LOT
BUS STATION
BUS ROUTE
2100 P.S.
1630 P.S.
CHERRY LANE
PURDUE UNIVERSITY GOLF COURSE
ROSS ADE STADIUM
STADIUM
STATE STREET

FIGURE 24 – SUB-ALTERNATIVE II/3-A – (COMMUTING TO AND FROM THE ACA


CHERRY LANE
2100 P.S.
ROSS ADE STADIUM
STADIUM
GRANT STREET
STATE STREET
NORTH RIVER ROAD
SOUTH RIVER ROAD
W A B A S H R I V E R

COMMUTING TO AND FROM THE ACADEMIC ZONE) locations of the parking facilities and the proposed bus routes. In both bus systems, the round trip length is about 3.2 miles. The requirments of each of these systems were estimated on the basis of the following operational criteria.

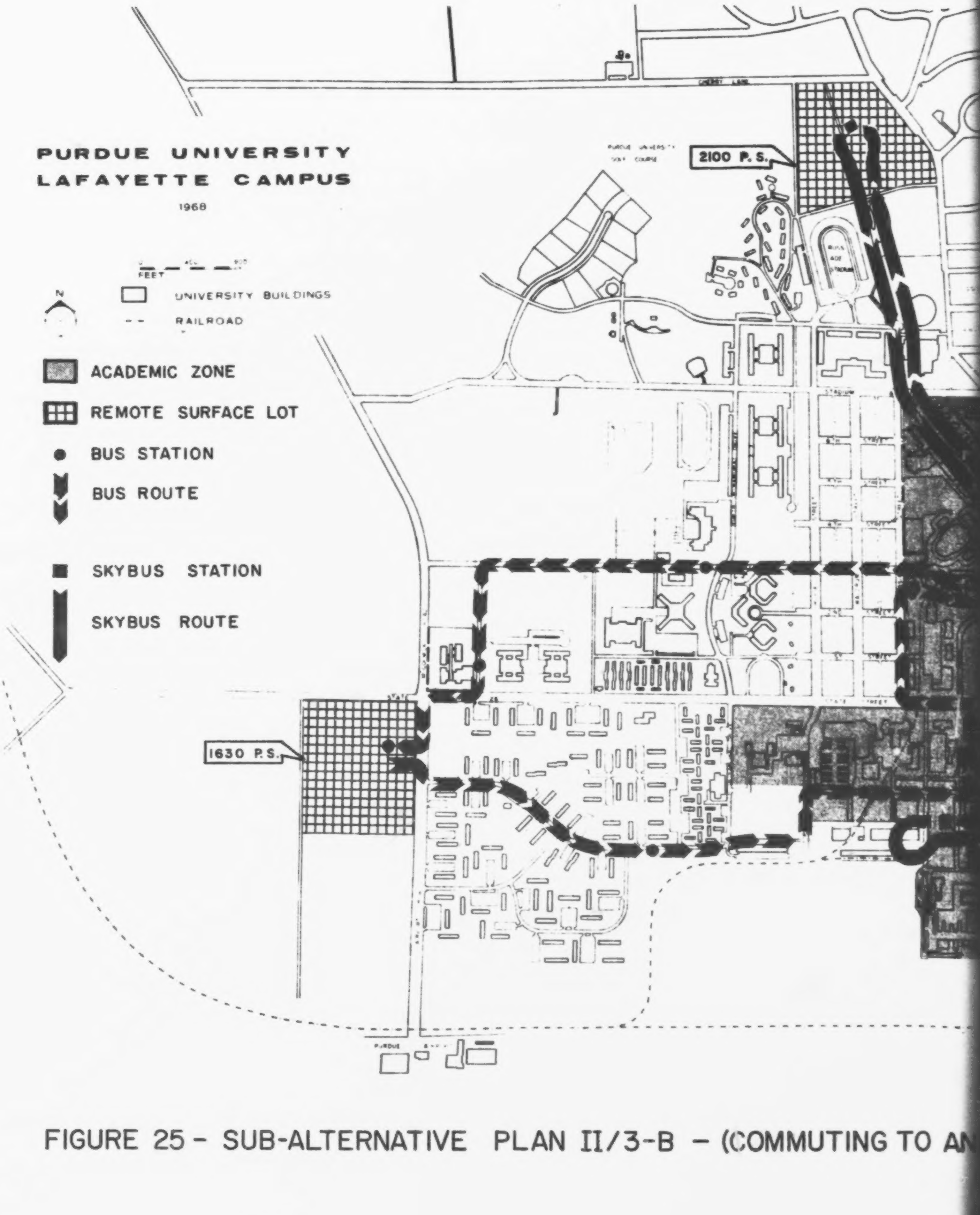
1. The system needed to move a peak load of about 1075 passengers from the parking facility and from the university housing facilities located along its route to the academic zone in not more than thirty minutes.
2. A minimum headway of about two minutes and a maximum of about five minutes are allowed.
3. The system is used from 7:00 a.m. till 6:00 p.m. on average weekdays and from 7:00 a.m. till 12:00 noon on Saturdays when classes are in session, and from 7:30 a.m. to 5:30 p.m. on average weekdays when classes are not in session.
4. The average speed of the bus on the round trip is about eight miles per hour including stops and time allowed between trips.
5. The peak occupancy of the bus is about seventy passengers (25).

On the basis of these criteria and the estimated peak load, thirteen bus units would be needed for each system. The detailed estimates of the requirements of the bus systems and the annual cost of implementing sub-alternative II/3-A appear in Appendix B - section 4.

Sub-Alternative II/3-B. A number of new intraurban transportation devices are presently being developed and tried. Questions are often raised as to their efficiency, economy, and advantages. This sub-alternative used an elevated skybus system to connect the Ross Ade Stadium parking lot to the academic zone. In this way, the sub-alternative provided a basis for evaluating the advantages of the device in meeting future demand for commuting to the academic zone. The skybus is basically a bus running on an exclusive elevated roadway. The operation of the system is fully automatic. Its vehicles can be run singly or in trains (26). The system was selected from among a number of other new transportation devices (e.g., moving sidewalks and carveyors) as its operational characteristics were found suitable for the situation at hand.

Figure 25 shows sub-alternative plan II/3-B. Apart from the proposed roadway for the elevated skybus system connecting the Ross Ade Stadium parking lot to the academic zone, all other elements of this plan are identical to those of sub-alternative II/3-A. In Figure 25, the skybus round trip is about 2.6 miles long. The requirements of the system were estimated on the basis of a peak load of 1075 passengers and according to the following operational criteria:

1. The system should be able to move a peak load of about 1075 passengers from the Ross Ade Stadium parking lot to the academic zone in not more than twenty minutes.


PURDUE UNIVERSITY
LAFAYETTE CAMPUS
1968
FEET
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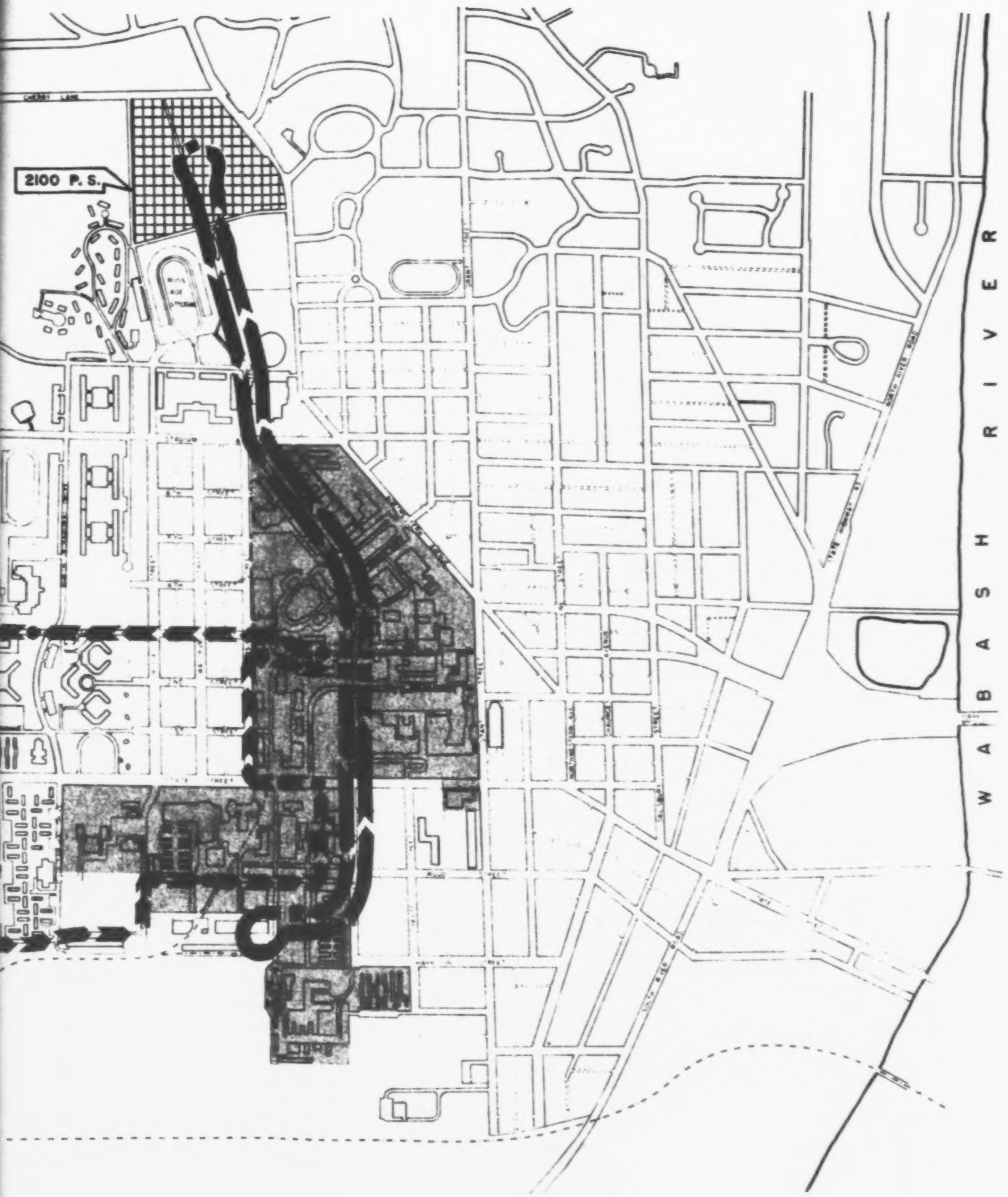
UNIVERSITY BUILDINGS
RAILROAD
ACADEMIC ZONE
REMOTE SURFACE LOT
BUS STATION
BUS ROUTE
SKYBUS STATION
SKYBUS ROUTE
2100 P. S.
1630 P.S.
PURDUE UNIVERSITY GOLF COURSE
CHERRY LANE
STADIUM
STATE STREET

FIGURE 25 - SUB-ALTERNATIVE PLAN II/3-B - (COMMUTING TO AN


CHERRY LANE
2100 P. S.
W A B A S H   R I V E R

- (COMMUTING TO AND FROM THE ACADEMIC ZONE)

2. A minimum headway of about two minutes and a maximum of about three minutes are allowed.
3. Two vehicles per train are used during peak use and only one during off-peak use.
4. The system is used from 7:00 a.m. to 6:00 p.m. on average weekdays and from 7:00 a.m. to 12:00 noon on Saturdays when classes are in session, and from 7:30 a.m. to 5:30 p.m. on average weekdays when classes are not in session.
5. The average speed of the skybus train is about 25 miles per hour including stops (26).
6. The peak occupancy per vehicle is about 50 passengers (26).

On the basis of these criteria and the estimated peak load, seven skybus vehicles would be needed. The detailed estimates of the requirements of the skybus system and the annual cost of implementing sub-alternative II/3-B appear in Appendix B - section 4.

Evaluation of Alternatives

In the following evaluation, two criteria are considered: convenience and cost. Because continuity in the circulation system, safety, and the potential for developing an aesthetically pleasing environment are about equally satisfactory in each of the alternatives, these criteria were not considered in the evaluation.

Convenience was measured in terms of three factors:

1. the average trip time from parking facilities to the academic zone. In estimating these averages, the focal point on the academic zone was taken as the hypothetical destination of all trips.
2. the average trip time from university housing facilities to the academic zone (focal point) if the mode of transportation is other than walking the total distance.
3. the maximum delay expected in bus and skybus trips. In bus and skybus systems, headways cannot be reduced below a certain minimum, and vehicle occupancies cannot be raised above a certain maximum. Therefore, a certain period of time is required to move all passengers to their destinations during the peak hours. This period of time is here referred to as the maximum expected delay. Students, in order to reach their classes in time, have to start their trips from residences early enough to allow for at least a portion of this maximum expected delay. Obviously, the higher this maximum expected delay, the less convenient the system becomes.

The alternatives are also evaluated in terms of their annual costs. This includes the annual costs of investment (construction and equipment) as well as the annual costs of maintenance and operation. The detailed estimates of these annual costs appear in Appendix B. Table 5 gives, for each alternative, the average trip time from parking facilities to the academic zone, the average trip time from university housing facilities to the academic zone, the maximum expected delay, and the estimated annual cost.

In terms of the three measures of convenience used in this evaluation, alternative II/1 appears to be the most convenient, and sub-alternative II/3-A the least convenient. Unlike what is generally believed, the use of the skybus in sub-alternative II/3-B was not as convenient as parking near destinations but was more convenient than the ordinary bus system. The inefficiency of providing intermediate stops along the roadway, however, requires that students living in university housing facilities walk to the terminal point to be able to use the system. Because of this, the system tends to lose one of its basic advantages, namely, high speed for residents of university facilities. From Table 5, it can also be noted that in alternatives II/2 and II/3, the possible maximum delays expected in bus and skybus trips represent a definite inconvenience. This inconvenience is totally absent in alternative II/1 (assuming adequate parking space is provided). In terms of cost, Table 5 shows that sub-alternative II/3-A has the lowest estimated annual cost while sub-alternative II/3-B has the highest. However, alternatives II/1 and II/2 are very close, in annual cost, to alternate II/3-A.

Table 5. Evaluation of Alternative Commuting Plans.

Alternatives		Criteria						
		Convenience						Cost
		Average trip time from parking facilities to the academic zone (focal point).		Average trip time from university housing facilities to the academic zone (focal point)[1]		Maximum delay expected in bus and skybus trips		Estimated annual cost (investment + maintenance and operation)[4] - 1966 dollars.
		Trip time (minutes)	Trip mode	Trip time (minutes)	Trip mode	Delay (minutes)	Trip mode	
Alternative II/1. Parking around the academic zone.		5	on foot	11	by auto then on foot	--	--	$654,250.00
Alternative II/2. Parking around the academic zone and bus system connecting university housing facilities to the academic zone.		5	on foot[2]	20[3]	by bus then on foot	18	by bus	$664,186.00
Alternative II/3. Remote parking connected to the academic zone by bus (or skybus) systems.	Sub-alternative II/3-A. Remote parking connected to the academic zone by bus systems.	17	on foot then by bus then on foot	20[3]	by bus then on foot	30	by bus	$636,114.00
	Sub-alternative II/3-B. Remote parking connected to the academic zone by a skybus system and a bus system.	10	on foot then by skybus then on foot	17	on foot then by skybus then on foot	18	by skybus	$982,998.00

[1] excluding pedestrian trips.

[2] for users of parking around the academic zone.

[3] including walking from residence to bus station.

[4] detailed calculations appear in Appendix B.

When the alternatives are evaluated on the basis of convenience and cost together, it is clear that alternative II/2 and sub-alternative II/3-B, because of their higher annual costs and/or lower levels of convenience (in terms of the three measures indicated above) would rank lower than alternative II/1 and sub-alternative II/3-A. By limiting the evaluation to alternative II/1 and sub-alternative II/3-A (on the grounds of their superiority) and by comparing their advantages and disadvantages, it can be seen that one offers a lower annual cost while the other offers a higher level of convenience. The comparison is obviously one between quantity and quality, and as such, it is objectively unfeasible. It can be concluded that in order to decide which of the two alternatives is more appropriate (in terms of the criteria set above), subjective value has to be assigned to the factor of convenience. Such an assignment should be made in accordance with standards and policies adopted by the university. The cost of alternative II/1, however, is not much greater than that of sub-alternative II/3-A while the convenience provided by alternative II/1 is much greater than that offered by sub-alternative II/3-A. On this basis, it is expected that alternative II/1 would be selected as the best plan by most decision-makers.

CHAPTER IV. CONCLUSIONS AND RECOMMENDATIONS

This study was directed toward the investigation of some aspects of the transportation problems on the Purdue Lafayette campus, the estimation of a number of its future transportation requirements, and the formulation of alternative plans to meet these requirements. On the basis of the findings of this study, the following conclusions and recommendations appear justified.

Conclusions

1. Based on the opinions of the university faculty and the potential capacity of the existing physical plant, an ultimate future enrollment of about 35,000 students seems reasonable. It is expected that about 35 percent of this ultimate enrollment would be graduate students and about 26 percent would be married students. For this ultimate enrollment, it is estimated that the university will employ about 9,450 full-time staff members.
2. On the basis of the envisaged university housing policy and the observed trend of student demand on university housing, it is estimated that, in the future (i.e., when the ultimate enrollment is attained), the university will provide housing for

about 55 percent of the undergraduate single students, 40 percent of the graduate single students, and 40 percent of the married students (graduate and undergraduate).

3. Analysis of the pedestrian circulation in and around the academic zone indicates that:
    a. the existing layout and use of the instructional facilities in the academic zone do not provide conditions of minimum pedestrian movement. A number of instructional facilities with high frequency of use are located on peripheral sites while some conveniently accessible central locations are used for facilities that are not used (or infrequently used) for instruction. This tends to decrease the efficiency of pedestrian circulation in the academic zone.
    b. pedestrian-vehicle conflicts exist and are expected to increase at a number of locations in the academic zone, and especially on State Street. Around the academic zone, pedestrian-vehicle conflicts are expected to significantly increase on University and Russel Streets between First and Third Streets and on Stadium Avenue south of Cary Hall.
4. Four interrelated student population characteristics were found to influence student demand on parking

around the academic zone: (1) size and composition of student population, (2) daytime population of students in the academic zone, (3) student behavioral patterns in using their automobiles to commute to the academic zone, and (4) the residential distribution of students on and around the campus. Forecasts were made for these four characteristics for the future. The future student demand for parking around the academic zone was also estimated from these student population characteristics. A student parking demand forecasting model thus developed indicated that the student demand for parking around the academic zone is expected to be about 3,685 parking spaces for the ultimate enrollment.

5. On the basis of the observed trend (1963-1967) in the number of parking spaces per full-time staff member working in the academic zone, future staff parking demand was estimated to be about 6,650 parking spaces. It was also estimated that 330 parking spaces will be needed for visitors' use.
6. It is expected that the parking facilities presently operated by the university in and around the academic zone, and an additional 1000 on-street free parking spaces around the academic zone will remain in use by commuters in the future. Thus, a net additional 4,330 parking spaces will be required

(for the future) to meet the parking demands of students, staff, and visitors at the time of ultimate enrollment. If these are provided in remote parking facilities, a bus system would be required to move the parkers to the academic zone. The peak load on such a system is estimated to be about 2,150 passengers in a 30-minute period.

7. Of the alternative plans developed to meet the future demands for commuting to and from the academic zone, two appear to offer reasonable solutions. In terms of annual cost, a plan that provides the net future parking demands of students, staff, and visitors in surface lots and multi-story garages on close-by locations around the academic zone (alternative II/1), would involve an estimated annual cost of about $654,250.00 An alternative plan that provides the same future parking demands in two surface lots located north of Ross Ade Stadium and on the southwest corner of Airport Road and State Street and connected to the academic zone by two street bus systems (sub-alternative II/3-A), would require an estimated annual cost of about $636,114.00. When convenience was measured by the average trip time from parking facilities to the academic zone, by the average trip time from university housing facilities to the academic zone, and by the maximum delay

expected for bus trips, it was found that the former offers a much higher level of convenience than the latter. On the basis of cost and convenience, it is expected that the former (alternative II/1) would be selected as the best plan by most decision-makers.

Recommendations

1. To maximize the efficiency of pedestrian circulation in the academic zone, it is recommended that:
   a. non-instructional facilities presently occupying central locations and having minimal functional linkages with other instructional facilities (e.g., Engineering Administration building, the power plant, and Agricultural Experiment Station) be, whenever feasible, relocated to make room for future instructional uses.
   b. infrequently used instructional facilities located in the central area be put to more intensive use in the future (e.g., Pierce Conservatory, Michael Golden Shops, and the Aeronautical and Engineering Sciences building).
   c. future instructional facilities planned for intensive use be centrally located (within 1100 feet of the focal point) whenever possible.
   d. the possibility of using centrally located facilities by functions (lecture halls, laboratories, offices, etc.) rather than by major field

(Chemistry, Education, Electrical Engineering, etc.) be investigated as a means of reducing the number of problematic pedestrian trips (which cannot be walked within the time-break allowed between classes).

2. To minimize future pedestrian-vehicle conflicts in and around the academic zone, it is recommended that:
   a. through vehicular traffic be eliminated on the north campus.
   b. vehicular traffic on Stadium Mall be eliminated or limited to one way in the south direction.
   c. vehicular traffic and curb parking be eliminated on Oval Drive (between Memorial Mall and State Street), Memorial Mall (between Purdue Mall and Central Drive), Central Drive (between the Chemistry building and Stanley Coulter building) and south of the Hall of Music.
   d. an open pedestrian underpass connecting the north and south campuses be provided under State Street along the east side of the Home Economics Administration building.
   e. a study be made of the pedestrian-vehicular conflicts on State Street resulting from the graduate housing complex south of State Street.

f. provision for separated pedestrian crossing be studied and appropriate traffic controls be used on Russell and University Streets at Second Street to secure safe crossings for the heavy concentrations of pedestrians at these locations

3. It is recommended that the future demands for non-pedestrian commuting to and from the academic zone be met by implementation of adequate plans. On the basis of cost and convenience as analyzed in this study, alternative plan II/1 appears to be best.

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APPENDIX A. SUMMARY OF RESULTS - FACULTY QUESTIONNAIRE ON UNIVERSITY POLICIES AFFECTING DEVELOPMENT OF MASTER PLAN OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

APPENDIX A. SUMMARY OF RESULTS - FACULTY QUESTIONNAIRE ON UNIVERSITY POLICIES AFFECTING DEVELOPMENT OF MASTER PLAN OF THE LAFAYETTE CAMPUS OF PURDUE UNIVERSITY

Please complete the following:

1. My rank is:

33%(1A)	Professor (323)	4% (1D)	Instructor (41)
29%(1B)	Associate Professor (290)	3% (1E)	Other (27)
31%(1C)	Assistant Professor		

2. My primary activity at Purdue is:

15%(1F)	Administration (144)	59%(1H)	Teaching (574)
20%(1G)	Research (187)	7%(1I)	Other (60)

3. I have been a member of the faculty of Purdue University for:

38%(1J)	Over 10 years (375)	23%(1K)	5 to 10 years (222)	36%(1L)	Less than 5 years (350)

____
(Name, printed please, optional)

BASE N = 985

4. My principal activity is in the:

23%(2A) School of Agriculture (221)

16%(2B) Schools of Engineering (151)

3%(2C) School of Home Economics (30)

24%(2D) School of Humanities, Social Science and Education (231)

3%(2E) School of Industrial Administration and Management (31)

2%(2F) School of Pharmacy and Pharmacal Sciences (22)

16%(2G) School of Science (156)

5%(2H) School of Technology (45)

2%(2I) School of Veterinary Science and Medicine (23)

2%(2J) University Administration (21)

4%(2K) Other (41) ______________________________

5. My principal assignment in the above School is in the following Department (School in Engineering):

____

ACADEMIC

6. In September 1966, the enrollment on the Lafayette Campus was approximately 21,400 students of which about 16,600 were undergraduates and 4,800 were graduate students. Five years ago, in September 1961, there were approximately 16,500 students of which about 13,400 were undergraduates and 3,100 were graduates. The maximum total of students on the Lafayette Campus should be limited to:

7%(3A) 20,000
18%(3B) 25,000
30%(3C) 30,000
12%(3D) 35,000
5%(3E) 40,000
1%(3F) 45,000
1%(3G) 50,000
4%(3H) Above 50,000
21%(3I) Do Not Know

7. Slightly more than 22% of the total students in 1966 were graduate students. In 1961, only about 19% were graduate students. Of the maximum total enrollment checked in Question 1, graduate enrollment should be limited to no more than:

8%(4A) 20%
32%(4B) 30%
19%(4C) 40%
16%(4D) 50%
3%(4E) 60%
1%(4F) 70%
0%(4G) 80%
5%(4H) Above 80%
15%(4I) Do Not Know

8. The standards for admission of undergraduate students in your school should be:

0%(5A) substantially lowered
2%(5B) slightly lowered
44%(5C) left unchanged
35%(5D) slightly raised
9%(5E) substantially raised
8%(5F) Do Not Know

9. The standards for admission of graduate students in your school should be:

0%(5G) substantially lowered

3%(5H) slightly lowered

50%(5I) left unchanged

28%(5J) slightly raised

8%(5K) substantially raised

9%(5L) Do Not Know

10. List any specific suggestions you have regarding changes in admission policies for undergraduate and for graduate students (use additional sheet if more space is required).

11. Do you believe any new academic schools or departments should be established on the Lafayette Campus within the next ten (10) years?

14%(6A) No

38%(6B) Yes

44%(6C) Do Not Know

If yes, list below in priority order the names of such schools or departments:

12. For optimum development of your Department (School, in Engineering), how many undergraduate students should be enrolled in your department by 1976-77?

4%(6D) less students than enrolled in 1966-67

12%(6E) about the same number as enrolled in 1966-67

17%(6F) slightly more students than enrolled in 1966-67

17%(6G) 1.5 times the number enrolled in 1966-67

16%(6H) 2 times the number enrolled in 1966-67

12. Continued.

6%(6I) 3 times the number enrolled in 1966-67

6%(6J) more than 3 times the number enrolled in 1966-67

19%(6K) Do Not Know

13. Same as Question 12 but for graduate students in your Department:

3%(7A) less students than enrolled in 1966-67

10%(7B) about the same number as enrolled in 1966-67

18%(7C) slightly more students than enrolled in 1966-67

19%(7D) 1.5 times the number enrolled in 1966-67

20%(7E) 2 times the number enrolled in 1966-67

7%(7F) 3 times the number enrolled in 1966-67

6%(7G) more than 3 times the number enrolled in 1966-67

15%(7H) Do Not Know

14. For optimum development of your Department (School, in Engineering), by 1976 the size of the staff (faculty plus clerical and service) should be:

0%(8A) less than in 1966-67

5%(8B) about the same as in 1966-67

24%(8C) slightly more than in 1966-67

30%(8D) 1.5 times the number in 1966-67

14. Continued.

19%(8E) 2 times the number in 1966-67

6%(8F) 3 times the number in 1966-67

5%(8G) more than 3 times the number in 1966-67

8%(8H) Do Not Know

15. Do you feel that the major facilities and/or equipment now available in your Department are adequate for current teaching needs.

64%(8I) No 31%(8J) Yes

If no, please list the major facilities and/or equipment needed.

16. Some departments schedule large sections for teaching undergraduates. For the teaching of undergraduate freshmen and sophomores in the future in my Department:

18%(9A) no large sections should be used

25%(9B) very few large sections should be used

24%(9C) about the current number of large sections should be used

11%(9D) slightly more large sections should be used

4%(9E) substantially more large sections should be used

13%(9F) Do Not Know

17. For the teaching of undergraduate juniors and seniors in the future in my Department:

35%(9G) no large sections should be used

25%(9H) very few large sections should be used

18%(9I) about the current number of large sections should be used

6%(9J) slightly more large sections should be used

2%(9K) substantially more large sections should be used

9%(9L) Do Not Know

18. For the teaching of graduate students in the future in my Department; class sizes typically:

10%(10A) should be no more than 10

22%(10B) should be no more than 15

25%(10C) should be no more than 20

18%(10D) should be no more than 25

12%(10E) could be more than 25

9%(10F) Do Not Know

19. Do you believe that major changes in methods of teaching will occur in your Department by 1976?

30%(10G) No 45%(10H) Yes 22%(10I) Do Not Know

If Yes, please state major changes you anticipate will occur.

20. Relative to present usage, to what extent will the following educational equipment or aids be used in 1976 in your Department?

	Increase Considerably	Increase Slightly	No Change	Decrease	Do Not Know
a. Instructional Television	30%(11A)	29%(11B)	19%(11C)	2%(11D)	16%(11E)
b. Computer-assisted Instruction	32%(11F)	25%(11G)	16%(11H)	0%(11I)	19%(11J)
c. Films, Slides, Filmstrips	28%(12A)	35%(12B)	21%(12C)	1%(12D)	10%(12E)
d. Audio Tapes	22%(12F)	28%(12G)	26%(12H)	1%(12I)	15%(12J)
e. Computerized Test Scoring and Analysis	27%(13A)	31%(13B)	20%(13C)	1%(13D)	15%(13E)
f. Tele-lectures (remote audio)	18%(13F)	27%(13G)	26%(13H)	1%(13I)	22%(13J)
g. Graphics, Models	19%(14A)	35%(14B)	24%(14C)	2%(14D)	15%(14E)

21. Relative to present operations, in 1976 what will be the requirements for local production of TV and film instruction materials?

	Increased Greatly	Increased Slightly	No Change	Decreased	Do Not Know
TV	32%(15A)	29%(15B)	12%(15C)	1%(15D)	23%(15E)
Film	24%(15F)	31%(15G)	15%(15H)	2%(15I)	23%(15J)

RESEARCH

22. Considering current research assignments in your Department, do you expect that the average porportion of faculty research time to teaching time by 1976-77 will:

3%(16A) substantially decrease
7%(16B) slightly decrease
39%(16C) stay about the same
26%(16D) slightly increase
14%(16E) substantially increase
8%(16F) Do Not Know

23. Considering current research assignments in your Department, do you believe that the average proportion of faculty research time to teaching time by 1976-77 should:

5%(16G) substantially decrease
12%(16H) slightly decrease
35%(16I) stay about the same
25%(16J) slightly increase
16%(16K) substantially increase
5%(16L) Do Not Know

24. Are there areas in which your Department does not have a current significant research program but in which such a program should be developed within the next ten years?

15%(17A) No
54%(17B) Yes
25%(17C) Do Not Know

If Yes, please list in priority order a brief descriptive name of these areas.

25. Do you feel that the research policies now maintained by the University are satisfactory?

27%(17D) No 43%(17E) Yes 26%(17F) Do Not Know

If No, please briefly state specific policies you feel should be adopted.

26. In addition to the major new facilities and/or equipment which you listed under Question 15 of the ACADEMIC portion of this survey, are there other major new facilities and/or equipment which should be furnished for research purposes by the University?

12%(17G) No 40%(17H) Yes 42%(17I) Do Not Know

If Yes, please list the major new facilities and/or equipment needed.

CONTINUING EDUCATION

27. The programs of continuing education (evening courses, short conferences, open seminars, etc.) currently vary by departments. On the basis of the current continuing education activity of your Department, the program offered by your Department on the Lafayette Campus should:

3%(18A) be substantially decreased 28%(18D) be slightly increased

3%(18B) be slightly decreased 25%(18E) be substantially increased

24%(18C) remain about as at present 13%(18F) Do Not Know

28. The programs of extension activity (advice and other assistance to governmental units, employment groups or individuals, etc.) also currently vary by departments. On the basis of the current extension activity of your Department, the programs offered by your Department on the Lafayette Campus should:

4%(18G) be substantially decreased
5%(18H) be slightly decreased
28%(18I) remain about as at present
22%(18J) be slightly increased
21%(18K) be substantially increased
17%(18L) Do Not Know

29. Are there any major functions other than academic, research, continuing education and extension which Purdue University should undertake within the next ten years?

35%(19A) No
15%(19B) Yes
47%(19C) Do Not Know

If Yes, please briefly describe them.

HOUSING

30. Purdue has operated on a completely voluntary housing policy since 1961. Under these circumstances the University residence halls accommodated 47.5% of the single undergraduate men and 56.8% of the single undergraduate women or a total of approximately 50% of all the single undergraduate men and women in September 1966.

On the basis of the current 50% fifugre and your estimate of University growth, the proportion of single undergraduate students to be housed by the University in the future should be:

2%(19D) substantially decreased
3%(19E) slightly decreased
23%(19F) maintained at the present level
24%(19G) slightly increased
30%(19H) substantially increased
18%(19I) Do Not Know

31. In September 1966, 32% of the single graduate men and 41% of the single graduate women or a total of 35% of the single graduate students elected to live in the Graduate House and 250 "overflow" spaces made available in the residence halls.

On the basis of this current demand and your estimate of University growth, the proportion of single graduate students housed in University operated Graduate Houses in the future should be:

3%(20A) substantially decreased
3%(20B) slightly decreased
15%(20C) maintained at the present level
29%(20D) slightly increased
32%(20E) substantially increased
17%(20F) Do Not Know

32. Out of the total enrollment of 21,407 undergraduate and graduate students in September 1966, 3,003 men and 1,001 women were registered as married students. The University accommodated 28.4% of these 4,004 married students in University operated apartments.

On the basis of the current use and your estimate of University growth, the proportion of married students housed in University operated apartments in the future should be:

4%(20G) substantially decreased
4%(20H) slightly decreased
15%(20I) maintained at the present level
26%(20J) slightly increased
38%(20K) substantially increased
13%(20L) Do Not Know

33. The University currently has some housing facilities which it makes available as rental housing to new faculty members for a maximum of two years. The University should:

4%(21A) not assist new faculty members with their housing needs

33. Continued.

91%(21B) assist new faculty members with their housing needs

3%(21C) Do Not Know

If you feel the University should assist new faculty members with their housing needs, please answer the following:

61%(21D) the present policy of some University rental units for a maximum of two years is satisfactory.

26%(21E) the present assistance policy is inadequate.

If you think the present policy is inadequate, please state how you feel the University should provide such housing assistance.

CULUTURAL ACTIVITIES AND RECREATION

34. Do you believe the cultural activities currently available at the Lafayette Campus are adequate?

26%(21F) No 66%(21G) Yes 5%(21H) Do Not Know

If No, please state what cultural activities you would like to see increased or developed.

35. Some support has been noted for a campus facility in which the visual arts (sculpture, paintings, etc.) of the University could be displayed. Do you favor such a campus facility?

17%(21I) No 68%(21J) Yes 13%(21K) Do Not Know

36. Should the University have a formal faculty club facility?

15%(22A) No 72%(22B) Yes 10%(22C) Do Not Know

37. If your answer to 36 is *Yes*, would you join such a club if it *did not* have a liquor privilege?

25(22D) No 48%(22E) Yes

38. If your answer to 36 is *Yes*, would you join such a club if it *did* have a liquor privilege?

8%(22F) No 61%(22G) Yes

39. Supposing that such a facility were to be realized, would you support it if it were located:

On the campus 70%(23A) Yes 19%(23B) No

Adjacent to the campus with adequate parking 76%(23C) Yes 14%(23D) No

Within 3 miles of the campus with adequate parking 56%(23E) Yes 31%(23F) No

40. Would you prefer such a club to provide (choose one)

2%(23G) Lounge, recreational facilities, meeting rooms but no food services

16%(23H) Lounge, recreational facilities, meeting rooms plus a luncheon service

71%(23I) Lounge, recreational facilities, meeting rooms, luncheon service and dinner

41. What is the maximum membership fee you would be willing to pay to become a member of a faculty club, assuming that you would be able to purchase food services at prices equivalent to those for similar services in the Union, said membership fee to be deducted monthly from your salary, in ten equal payments?

22%(24A) none   48%(24B) $10 a month

17%(24C) $15 a month   5%(24D) $25 a month

42. If you are willing to pay a fee, should the membership fees vary by rank of faculty member, i.e., a lower fee for an assistant professor than for a full professor?

44%(24E) No   37%(24F) Yes

43. Should membership be extended to:

64%(24G) Faculty only

11%(24H) Alumni

16%(24I) Friends of the University

4%(24J) Other (Please specify)______________________________

44. One method of financing a facility for a faculty club is to sell shares later to be amortized or sold. Would you subscribe to this opportunity if the amount per share were

59%(25A) I would not subscribe   28%(25B) $500   2%(25C) $1000

45. Please list any other comments you have regarding the establishment of a faculty club.

CAMPUS BEAUTIFICATION

46. Do you find the overall design, architecture, and landscaping of the Lafayette Campus to be:

19%(25D) Very poor   19%(25G) Good

23%(25E) Poor   6%(25H) Very good

32%(25F) Fair   1%(25I) Do Not Know

47. Assuming that sufficient parking space could be constructed adjacent to the campus on its perimeter, would you advocate that major areas on the campus now devoted to parking be developed as landscaped greensward?

30%(25J) No   59%(25D) Yes   8%(25L) Do Not Know

48. Assuming that adequate parking is constructed on the perimeter of the campus, should all motor vehicle traffic, except necessary service and delivery vehicles, be barred from the central campus?

37%(26A) No   49%(26B) Yes   7%(26C) Do Not Know

59. Please list any suggestions you have for future development relative to the design architecture, and landscaping of the Lafayette Campus.

OTHER

50. Considering the various services now provided by the University (photographic, duplicating, computing, machine shop, campus mail, transportation, etc.), do you know of services not now provided which will be required by 1976?

77%(26D) No   18%(26E) Yes

If Yes, please list them in order of priority.

51. Do you find all of the various services now provided to be adequate?

41%(26F) No 50%(26G) Yes

If No, please state the improvements needed.

52. Do you know of any of the adequate services now provided which will need to be expanded greatly during the next ten years (expanded substantially more than that dictated by University growth)?

67%(26H) No 22%(26I) Yes

If Yes, please list them and note amount of expansion required and why.

53. The current University policy is to provide in all new construction an individual air conditioned office of 120 square feet for each full time faculty member with academic rank of instructor and above. This amount of space is:

1%(27A) substantially more than required

4%(27B) slightly more than required

55%(27C) about right

23%(27D) slightly less than required

9%(27E) substantially less than required

4%(27F) Do Not Know

54. The Varsity Athletic Program of the University currently emphasizes football and basketball and provides programs in several additional areas. Do you feel any changes are desirable in the Varsity Athletic Program within the next ten years?

39%(27G) No 27%(27H) Yes 28%(27I) Do Not Know

If Yes, please state the changes you feel to be desirable.

55. Please list any other comments you have relative to any matter which would affect the updating of the Master Plan of physical facilities of the Lafayette Campus. (Attach as many pages as necessary).

Your cooperation in completing this detailed questionnaire is most appreciated. It is a real way for you to contribute to the planning of the Lafayette Campus.

APPENDIX B. ALTERNATIVE COMMUTING PLANS - ESTIMATED ANNUAL COSTS

APPENDIX B. ALTERNATIVE COMMUTING PLANS - ESTIMATED ANNUAL COSTS

This appendix comprises four sections:

1. Estimated annual costs of different types of parking facilities (per parking space).
2. Alternative II/1 - estimated annual cost.
3. Alternative II/2 - estimated annual cost.
4. Alternative II/3 - estimated annual cost.

Investment costs (constructions and equipment) are based on information as of 1966. Annual costs of investment are estimated on the basis of an interest rate of 5.25 percent and according to the expected economic life time of the item under consideration. Average total annual cost includes both investment cost and maintenance and operation costs.

Section 1 - Estimated Annual Costs of Different Types of Parking Facilities (Per Parking Space)

The following is a comparison between the estimated annual costs of providing parking spaces in different types of facilities. The estimates are made according to the following assumptions:

1. Parking facilities provided on land owned by Purdue University require no expenditures for land acquisition.

2. Cost of land in the first row of blocks around the academic zone is about $4.00 per square foot (as of 1966) (27).
3. Above ground garages are four-stories high.
4. One parking space in a four-story garage needs about 100 square feet of land area (28).
5. One parking space in a surface parking lot needs about 300 square feet of land area (27).

Parking in Underground Garages on University Owned Land - Annual Cost Per Parking Space.

- economic life = 40 years (27)
- cost of construction = $4,000.00 (27)
- cost of land = $--------
- total cost of investment = $4,000.00
- capital recovery factor = .060325 (29)
- annual cost of investment = $ 241.00
- annual cost of maintenance and operation = $ 100.00 (27)
- annual cost (total) = $ 341.00

Parking in Four-Story Garages on Non-University Owned Land - Annual Cost Per Parking Space.

- economic life = 40 years (27)
- cost of construction = $1,500.00 (27)
- cost of land = $ 400.00
- total cost of investment = $1,900.00
- capital recovery factor = .060325 (29)

- annual cost of investment = $ 115.00
- annual cost of maintenance and operation= $ 50.00 (27)
- annual cost (total) = $ 165.00

Parking in Surface Lots on Non-University Owned Land - Annual Cost Per Parking Space.

- economic life = 20 years (27)
- cost of construction = $ 300.00
- cost of land = $1,200.00
- total cost of investment = $1,500.00
- capital recovery factor = .08197 (29)
- annual cost of investment = $ 123.00
- annual cost of maintenance and operation= $ 50.00 (27)
- annual cost (total) = $ 173.00

Parking in Surface Lots on University Owned Land - Annual Cost Per Parking Space.

- economic life = 20 years (27)
- cost of construction = $ 300.00 (27)
- cost of land = $--------
- total cost of investment = $ 300.00
- capital recovery factor = .08197 (29)
- annual cost of investment = $ 24.60
- annual cost of maintenance and operation= $ 50.00 (27)
- annual cost (total) = $ 74.60

Section 2 - Alternative II/1 - Estimated Annual Cost

Future parking demand was estimated to be 3,685 parking spaces for students, 6,650 for staff, and 330 for visitors. Of these, the university presently (1968) provides 5,633 parking spaces and about 1,000 on-street parking spaces are assumed to remain available in the future. The present parking supply will be reduced by 302 parking spaces due to the proposed changes in the academic zone. Therefore, the net number of parking spaces which should be added in the future is about 4,330 parking spaces. In this alternative, an additional 315 parking spaces presently provided in parking lots will be removed upon construction of the proposed multi-story garages. Therefore, the net additional parking demand in this alternative is about 4,650 parking spaces.

Annual Cost. In alternative II/1, 1,250 parking spaces are provided as surface parking on university owned land and 3,400 parking spaces are provided in four-story above ground garages on non-university owned land.

According to Appendix B - Section 1, the annual cost of providing these numbers and types of parking spaces is estimated to be 1,250 x 74.60 + 3,400 x 165.00 = $654,250.00.

Section 3 - Alternative II/2 - Estimated Annual Cost

In this alternative, the street bus system provided between university housing facilities and the academic zone (Figure 23) will have to carry an estimated peak load of about 430 students around 8:30 a.m. On the basis of the operational criteria outlined in the description of this alternative in the text, the annual cost of providing this bus system is estimated as follows:

- economic life of bus units = 12 years (27)
- capital cost per bus unit = $30,000.00 (27)
- capital recovery factor = 0.11785 (29)
- annual cost of investment per bus unit = $ 3,536.00
- mileage per bus unit per year = 13.75 daily trips x 196.2 full days x 5.00 miles per trip to this mileage, 10 percent is added to provide for necessary non-assigned trips = 13,481 miles
- total mileage per bus unit per year = 14,829 miles
- cost of maintenance and operation per vehicle mile = $ 0.65 (27)
- annual cost of maintenance and operation per bus unit = 14,829 x 0.65 = $ 9,639.00
- annual cost per bus unit (investment + maintenance and operation) = 3,536.00 + 9,639.00 = $13,175.00
- number of bus units needed = 8 + one additional unit in maintenance or repair = 9 bus units
- annual cost of the bus system (total) = 8 x 13,175.00 + 3,536.00 = $108,936.00

On the other hand, if the bus system were not used, it would have required 600 additional parking spaces around the academic zone (the number of spaces expected to be used by students living in university housing facilities). If these spaces were provided in four-story garages on non-university owned land, they would have cost about 600 x 165.00 = $99,000.00.

The estimated annual cost of providing all the future parking demand around the academic zone (alternative II/1) is $654,250.00. If the bus system is used, the total parking demand around the academic zone will be reduced by 600 spaces. This means that the annual cost of providing the rest of the parking demand around the academic zone would be about $654,250.00 - 99,000.00 = $555,250,00. This total cost would have been higher if the substituted parking spaces were provided in surface parking on university owned land.

Accordingly, the annual cost of alternative II/2 is estimated to be about 555,250.00 + 108,936.00 = $664,186.00.

Section 4 - Alternative II/3 - Estimated Annual Cost

In this alternative, the two remote parking facilities are connected to the academic zone by two street bus systems in sub-alternative II/3-A and by a combination of a skybus system (from the Ross Ade Stadium parking lot) and a street bus system (from the Airport Road parking lot) in sub-alternative II/3-B. The annual costs of the parking facilities, the street bus systems, and the skybus system are here estimated separately. The annual costs of sub-alternatives II/3-A and II/3-B are then obtained.

Annual Cost of Parking Facilities. According to Appendix B - section 1, the annual cost of providing 3,730 parking spaces in remote parking lots on university owned land = 3,730 x 74.60 = $278,258.00.

Annual Cost of the Street Bus Systems. The two bus systems connecting the Ross Ade Stadium parking lot and the Airport Road parking lot to the academic zone are almost identical in load and round trip length. The estimates of the annual costs are thus made per system and on the basis of the operational criteria outlined in the description of sub-alternative II/3-A in the text.

- economic life of bus units = 12 years (27)
- capital cost per bus unit = $30,000.00 (27)
- capital recovery factor = 0.11785 (29)
- annual cost of investment per bus unit = $ 3,536.00
- mileage per bus unit per year = 19.30 daily trips x 196.20 full days x 3.20 miles per trip (classes in session) + 13.20 daily trips x 80.00 full days x 3.20 miles per trip (classes not in session) = 15,496 miles
  to this mileage, 10 percent is added to provide for necessary non-assigned trips.
- total mileage per bus unit per year = 17,046 miles
- cost of maintenance and operation per vehicle mile = $ 0.65 (27)
- annual cost of maintenance and operation per bus unit = 17,046 x 0.65 = $11,080.00
- annual cost per bus unit (investment + maintenance and operation) = 3,536.00 + 11,080.00 = $14,616.00
- number of bus units needed per system = 12 + one additional unit in maintenance or repair = 13 bus units
- annual cost per bus system (total) = 12 x 14,616.00 + 3,536.00 = $178,928.00

Annual Cost of the Skybus System. In sub-alternative II/3-B, the skybus system is used to connect the Ross Ade Stadium parking lot to the academic zone. On the basis of the operational criteria outlined in the description of this sub-alternative in the text, its average total annual cost is here estimated according to information provided by the manufacturer (26).

- economic life of roadway and control equipment = 40 years

- cost of roadway construction and control equipment:
  - at grade station = $ 727,280.00
  - three aerial stations = $2,031,840.00
  - roadway construction:
    - . curved single track - at grade (1300 feet) = $ 100,724.00
    - . curved single track - aerial (1700 feet) = $ 321,300.00
    - . straight double track - aerial (5400 feet) = $1,382,400.00
    - . total cost of roadway (including engineering and administration) = $2,020,954.00

  - one transfer table = $ 43,503.00
  - heating installation = $ 76,740.00
  - automatic train operation system = $ 165,876.00
  - power system = $ 512,118.00
  - facilities for maintenance and repair (to handle 10 vehicles) = $ 23,448.00
  - audio and visual system = $ 47,334.00
  - spare parts = $ 100,000.00
  - total cost of investment for roadway construction and control equipment = $5,749,093.00

- capital recovery factor (for roadway and equipment) = 0.060325 (29)

- annual cost of investment for roadway construction and control equipment = $ 346,814.00

- economic life of vehicles = 20 years
- capital cost per vehicle = $ 93,910.00
- capital recovery factor (for vehicles) = 0.08197 (29)
- annual cost of investment per vehicle = $ 7,698.00
    - mileage per vehicle per year = 44.00 daily trips x 196.20 full days x 2.60 miles per trip (classes in session) + 35.30 daily trips x 80.00 full days x 2.60 miles per trip (classes not in session) = 29,788 miles
    - cost of maintenance and operation per vehicle mile = $ 0.70
    - annual cost of maintenance and operation per vehicle = 29,788 x 0.70 = $ 20,852.00
    - annual cost per vehicle (investment + maintenance and operation) = 7,698.00 + 20,852.00 = $ 28,550.00
    - number of vehicles needed = 6 + one additional vehicle in maintenance or repair = 7 vehicles
    - annual cost of vehicles = 6 x 28,550.00 + 7,698.00 = $178,998.00
    - annual cost of the skybus system (roadway, control equipment, and vehicles) = 346,814.00 + 178,998.00 = $525,812.00

Annual Costs of Sub-alternatives II/3-A and II/3-B. On the basis of the above estimates,

- annual cost of sub-alternative II/3-A = 278,258.00 + 2 x 178,928.00 = $636,114.00
- annual cost of sub-alternative II/3-B = 278,258.00 + 525,812.00 + 178,928.00 = $982,998.00